ATOMIC STRUCTURE STUDIES OF Br IN THE VACUUM ULTRAVIOLET REGION

ABSTRACT

OF THE

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

PHYSICS

BY

RIYAZ AHEMAD

UNDER THE SUPERVISION OF

PROF. RAHIMULLAH KHAN

DEPARTMENT OF PHYSICS
ALIGARH MUSLIM UNIVERSITY
ALIGARH-202002 (INDIA)

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ABSTRACT

This thesis entitled "Atomic structure studies of Br in the vacuum ultraviolet region" comprises of four different atomic spectra of bromine viz; Br III, IV, V and VI. The analyses are based on the identification of 1480 transitions yielding a consolidated list of 446 energy levels of which 172 are new. 736 new spectral lines have been classified. The thesis is divided into six chapters.

Chapter 1 deals with the basic theory of atomic spectra, comprising of the Central-Field Theory, a brief account of Hartreė-Fock formalism, Slater Theory, Cowan's approach and ab initio calculations (relativistic Hartree-Fock calculation) involved in our analyses. Moreover the Rydberg series, ionization potential and its spectroscopic determination, Isoselectronic sequences and their utility in the analysis of atomic spectra are also discussed briefly.

Chapter 2 is devoted to describe the experimental details of the work concerning the light source and the spectrograph used, experimental recording of the spectrograms (made at Physics Department, St. Francis Xavier University, Antigonish, Canada and at Zeeman laboratory, Amsterdam for supplemented data of lower region below 300Å), measurement and establishment of the line list and separation of the different ionization stages present on our spectrograms. We estimate the accuracy of our measured wavelength for sharp and unblended lines to be ±0.005 Å.

Chapters 3-6 are the analyses and discussions part, dealing with third, fourth, fifth and sixth spectra of bromine i.e. Br III, Br IV, Br V and Br VI respectively.

In chapter 3, we have described revised and extended analysis of doubly ionized bromine. This is neutral Arsenic (As I) -like spectrum with ground configuration $4s^24p^3$. It is a 3-electron system possessing a complex structure. Its theoretical structure was predicted using Cowan's Configuration Interaction code. The excited configurations $4s4p^4 + 4s^24p^2$ (4d + 5d + 6d+5s + 6s+7s) in the even parity system and $4s^24p^2$ (5p + 4f) in the odd parity system have been studied. Relativistic

[artree–Fock (HFR) and least squares fitted (LSF) parametric calculations were used) interpret the observed spectrum. 159 energy levels of Br III have now been stablished; 43 being new. Out of 504 spectral lines classified, 209 are new. The pectrum is analyzed in the region 400–4600Å. The configurations studied are shown 1 Fig 1.

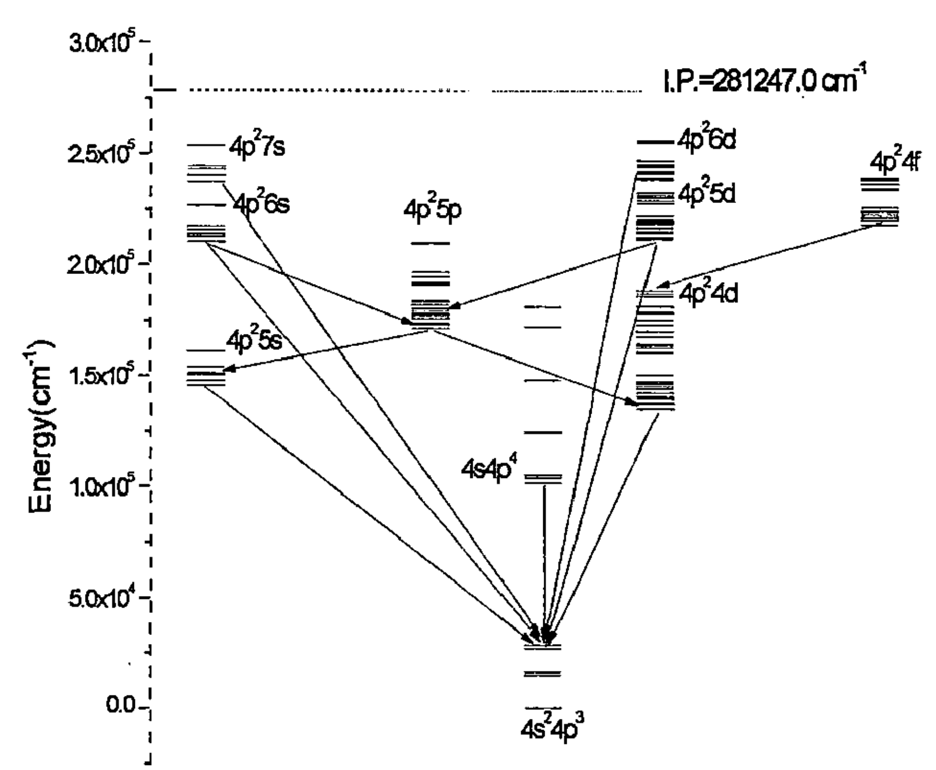

Fig. 1. Energy level diagram of Br III

The analysis of the Ge I-like spectrum of Br IV has been presented in Chapter . In this chapter the earlier work has been revised and extended to $3d^{10}4s^24p$ 5p+4f+5f) + $3d^{10}4s4p^2$ (4d+5s) + $3d^{10}4p^4$ configurations. The ground configuration of r IV $3d^{10}4s^24p^2$, the excited configurations $3d^{10}4s4p^3$ + $3d^{10}4s^24p$ (4d + 5d + 6d + 5s 6s + 7s) in the odd parity system and $3d^{10}4s^24p$ (5p +4f + 5f) + $3d^{10}4s4p^2$ (4d+5s) +

$3d^{10}\,4p^4$ in the even parity system have been studied. Relativistic Hartree–Fock (HFR) and least squares fitted (LSF) parametric calculations were used to interpret the observed spectrum. 120 energy levels of Br IV have been established; 58 being new. Among 424 spectral lines, 277 are newly classified. The levels $4s4p^3\,{}^5S_2$, $4s^24p4d\,{}^3F_4$ and 4p5p (${}^3P_{0,1}$, ${}^3D_{1,2}$, ${}^3S_1$) are revised. The ionization limit is determined as 385390±100 cm^{-1} (47.782± 0.012 eV). The spectrum has been studied in the 319–2350Å wavelength region. An isoelectronic plot of Br IV configurations has been shown in Fig. 2 and configurations studied in Fig. 3.

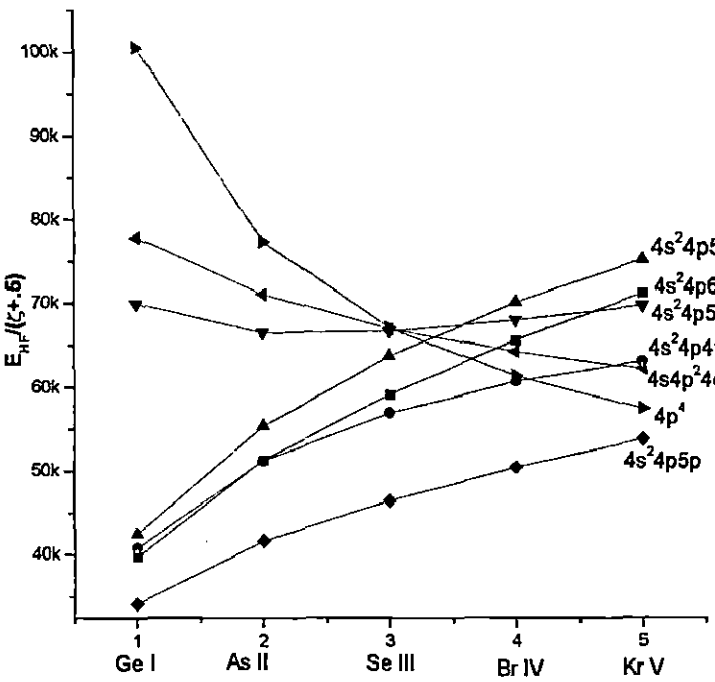

Fig. 2. Isoelectronic sequence extrapolation of Br IV

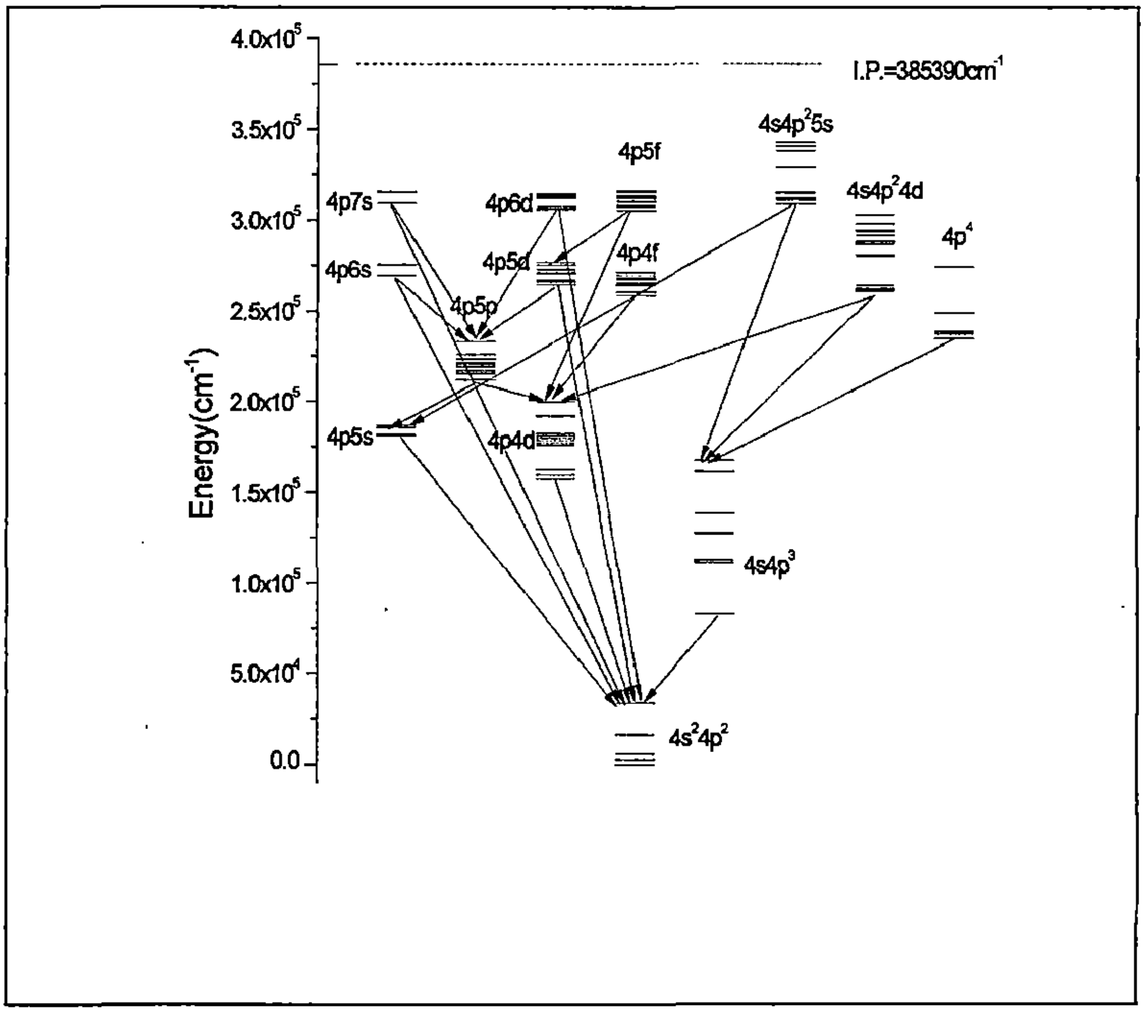

Fig. 3. Energy level diagram of Br IV.

An extended analysis of fifth spectrum of bromine Br V (Ga I-like) spectrum is described in the chapter 5. The spectrum is analyzed in the 200–2400Å wavelength region. The ground configuration of Br V is $4s^24p$. The excited configurations $4s4p^2$+$4s^2$(4d+5d+5s+6s+7s+5g+6g) + 4s4p(5p+4f) + $4p^24d$ in the even parity system and the $4p^3$ + $4s^2$(5p+6p+7p+4f) +4s4p4d + 4s4p5s configurations in the odd parity system have been studied. Relativistic Hartree–Fock (HFR) and least squares fitted (LSF) parametric calculations were used to interpret the observed spectrum. 99 levels of Br V have now been established, 43 being new. Among 394 classified spectral lines, 181 are newly classified. The level $4s^27s\ ^2S_{1/2}$ is revised. The ionization limit is determined as 479657±200 cm^{-1} (59.470±0.025 eV). The configurations studied in the present work are shown in Fig. 4.

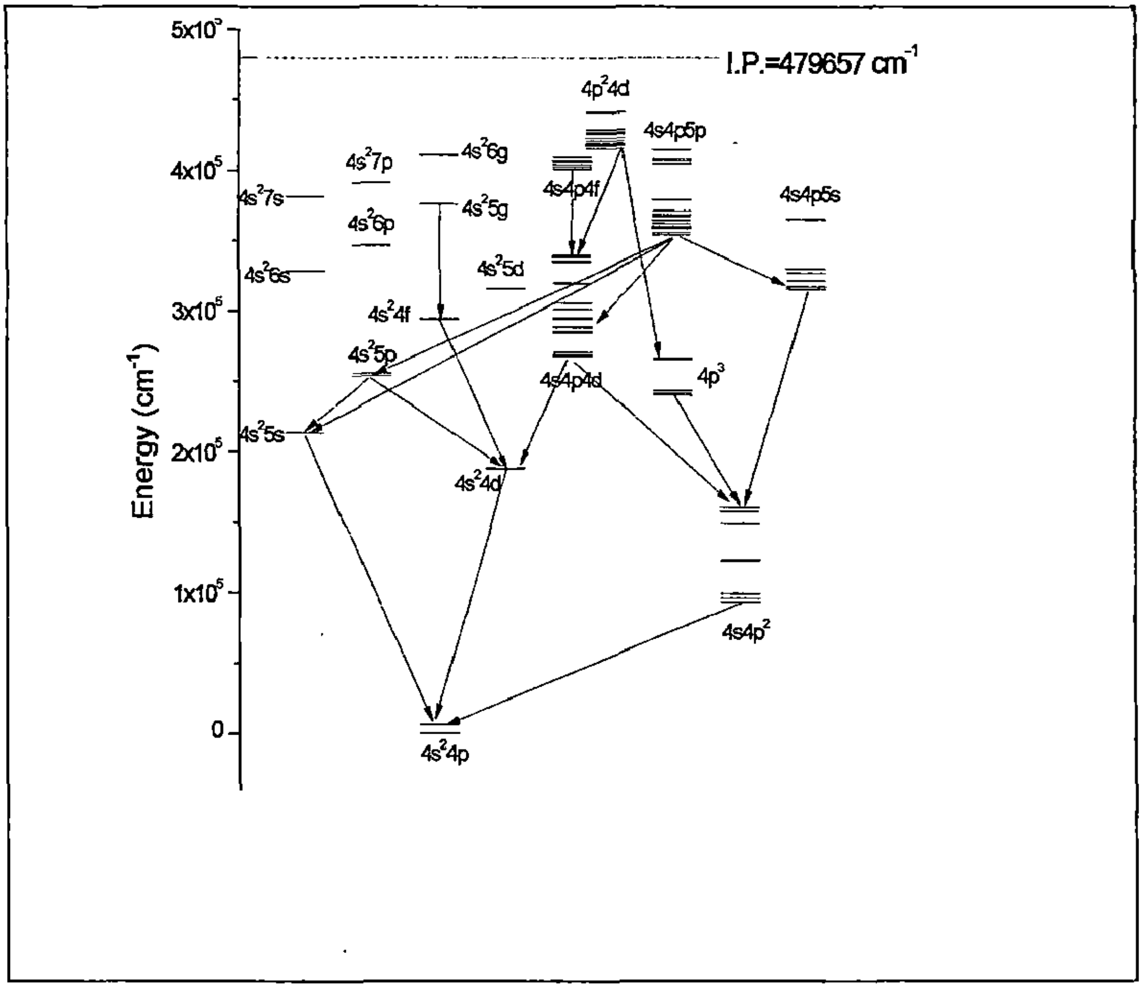

Fig. 4. Energy level diagram of Br V.

Chapter 6 deals with the revised and extended analysis of sixth spectrum of bromine (Br VI) which is neutral zinc (Zn I)-like. The spectrum has been studied in the 150-2060Å wavelength region. The ground configuration of Br VI is $3d^{10}4s^2$ and the excited configurations $3d^{10}4s$ (4p+5p+6p+7p+4f+5f) + $3d^{10}4p4d$ + $3d^{10}4p5s$ in the odd parity system and $3d^{10}4s$ (4d+5d+6d+5s+6s+7s+8s+5g+6g) + $3d^{10}4p^2$ in the even parity system have been studied. The work extended to the study of new configurations $3d^{10}4s$(6s, 7s, 8s, 6p, 7p, 5d, 6d, 5f, 5g, 6g). Relativistic Hartree-Fock (HFR) and least squares fitted (LSF) parametric calculations were used to interpret the observed spectrum. A total of 68 levels of Br VI have been established, out of which 28 are new. Two previously reported levels viz. 4p4d $^1D_2$ and $^3F_4$ are revised. Among 158 spectral lines, 69 are newly classified. The value of the ionization potential has been determined as 704850 ± 200 cm^{-1} (87.390 ± 0.025 eV). An energy level diagram of Br VI has been depicted in Fig. 5.

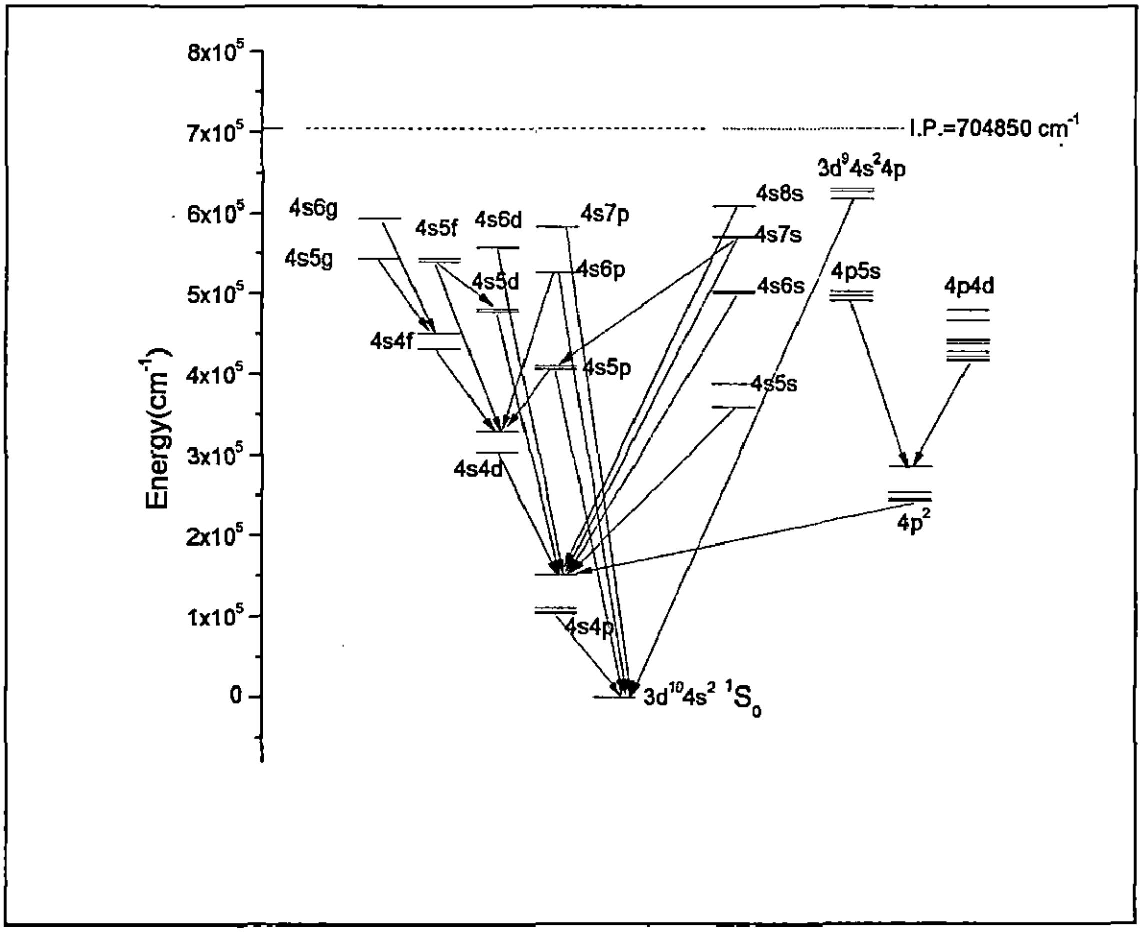

Fig. 5. Energy level diagram of Br VI.

In the last section conclusion of the work presented in the thesis and appendix are given. Spectrograms of bromine are reproduced covering the spectral region 300 - 2080Å. Prominent impurity lines of O, Al and C are marked together with strong Br III, IV, V and VI lines.

List of Publications:

A. In refereed journals

[1] "*Extended analysis of fifth spectrum of bromine: Br V*"
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2014

Dedicated to my parents

Declaration

I, "**Riyaz Ahemad**" student of Ph.D. hereby declare that the thesis entitled "**Atomic structure studies of Br in the vacuum ultraviolet region**" which is submitted by me to the Department of Physics, Faculty of Science, AMU, Aligarh in partial fulfillment of the requirement for the award of the degree of Doctor of Philosophy has not previously formed the basis for the award of any Degree, Associateship, Fellowship or other similar title or recognition. This is to declare further that I have also fulfilled the requirements of the Ordinances (Academic) for Doctor of Philosophy.

Riyaz Ahemad

Place: Aligarh

(Riyaz Ahemad)

Date: 08/09/2014

Prof. Rahimullah Khan
Chairman

DEPARTMENT OF PHYSICS
ALIGARH MUSLIM UNIVERSITY
ALIGARH – 202 002, INDIA
Tel: (Off.) +91 571 2701001
FAX: +91 571 2701001
E-mail: rahimullah@rediffmail.com
Mobile: 09319683858

Certificate

On the basis of declaration submitted by **Mr. Riyaz Ahemad** student of Ph.D., I hereby certify that the thesis entitled, "**Atomic structure studies of Br in the vacuum ultraviolet region**" which is submitted to the Department of Physics, Faculty of Science, AMU, Aligarh in partial fulfillment of the requirement for the award of the degree of Doctor of Philosophy, is an original contribution with existing knowledge and faithful record of research carried out by him under my guidance and supervision.

To the best of my knowledge this work has not been submitted in part or full for any other Degree or Diploma to this University or elsewhere.

Rahimullah

(PROF. RAHIMULLAH KHAN)

(Supervisor)

Place: Aligarh

Date: 08.9.2014

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Riyaz Ahemad

(Riyaz Ahemad)
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INTRODUCTION

Spectroscopy is the study of interaction of light with matter. It is the most powerful scientific tool for studying atomic and molecular structure. Spectroscopy forms the link between astronomy and fundamental physics at atomic and molecular levels [1]. The earliest reference of optical spectroscopy is found in the book *Opticks* (1704) written by Isaac Newton [2]. Newton had described his famous experiment in this treatise, in which sunlight passing through a glass prism is resolved into its constituent colours. The radiation from different atoms and ions produced by various light sources, when examined with a spectroscope, reveals properties of the valence electrons involved. This is due to the fact that the spectrum of each atom or ion is unique, in pattern of lines where wavelengths and relative intensities of lines are characteristics of that particular ion or atom only. Atomic spectroscopy may be used in determination of elemental composition of matter by its electromagnetic spectrum. It plays a key role in astrophysics, biological monitoring, metal analysis of enzymes etc.

Astrophysicists and fusion researchers have always demanded accurate data on ionized atoms. The progress on the knowledge of simple spectra has been very satisfactory in past few decades. However; the information on the complex spectra is still incomplete. There are many unidentified spectral lines of astrophysical importance. These spectral lines may be due to the transitions between the excited configurations of some species. The experimental and theoretical researches in the field of spectroscopy have already contributed much to our knowledge concerning the physical nature of matters, not only of earth but of the sun, interstellar space and distant stars.

Bromine is a chemical element with symbol Br, and atomic number of 35. The knowledge of atomic structure constants of this element is of considerable scientific importance because of its great affinity in forming chemical compounds which may be a potential candidate for chemical lasers [3]. Atomic transitions of the some ions of bromine like Br IV and Br V have been studied in recent past in our laboratory; therefore to avail more information and atomic data in the sequence we have taken up the analyses of ionized bromine spectra.

This thesis comprises of six chapters. In it we have presented the atomic structure studies of bromine in the vacuum ultraviolet region i.e. third spectrum to sixth spectrum of bromine (Br III – Br VI). The spectroscopic analysis of Br III began in 1935; however, a comprehensive investigation appeared in the years 1956, 1961 and 1986. Br IV and Br V began in 1933, and Br VI began in 1934. Most of the research work done so far, on these four spectra involved only the ground configuration and the lowest excited configurations. In these analyses first excitations of the outer electron and internal excitation of the s shell electron were studied.

In the present work we have extended the analyses considerably. We have included the next excitations of the outer electron and the further excitations from the lower excited configurations.

Here we have introduced the bromine atom and our work on it. The first chapter of the thesis presents a brief introduction to the theoretical background of atomic structure calculations. The second chapter gives the experimental details concerned with the present work. The third to sixth chapters are devoted to describe the detailed structure and analyses carried out for the third, fourth, fifth and sixth spectra of bromine respectively in the light of Hertree-Fock relativistic calculations. Conclusions of the present work alongwith a future scope of work are given in the last chapter of the thesis. The reproduction of a few spectra of bromine that are used for the present investigations are given in the appendix.

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[1] Pradhan Anil K and Nahar Sultana N. Atomic Astrophysics and Spectroscopy. Cambridge University Press 2011.

[2] Rasheed Tabish. Spectral studies of polyatomic molecules., India: Aligarh Muslim University, Aligarh; 2010 [PhD Thesis].

[3] Wujec T, Baclawski A, Golly A, Ksiazek I. Studies of Bromine spectrum and determination of transition probabilities for Br I and Br II lines. Acta Physica polynica A. 1999; 96: 333-40.

CHAPTER 1

Theory of Atomic Structure Calculations

1.1 Theoretical background

The postulates of Bohr's theory, laid the foundation for basic theory of atomic spectra and structure of atoms. He suggested that the electrons were confined in the clearly defined, quantized orbits of fixed energies around the nucleus. Electron could jump from one state to another state only by emitting or absorbing a specific amount of energy (photon) provided it is permitted by the selection rules. Using the idea of Louis de Broglie and the work of contemporary physicists which strengthen the quantum nature of atom, Erwin Schrödinger described the electrons in these states as three dimensional wave functions rather than just a point particle and hence developed a mathematical model. Certain spectral and structural features of atoms having more than one electron were explained by this mathematical model in much better way [1].

One electron systems (like H- atom) are two body problems whose exact solutions involving even the relativistic quantum mechanics have been worked out satisfactorily [2]. The results obtained for one electron system are in good agreement with experiment. For more than one electron system (many body problem), with many electron configurations, the theoretical treatment becomes so complex that it becomes almost impossible to obtain an exact solution and we look for satisfactory approximations to solve the problem. Various approximations are used for this purpose; One of the most important being 'Central-Field Approximation', good enough to give good qualitative and quantitative agreement with experiment. The theoretical treatment is generally based on the assumption that the electron may be regarded to the first approximation as moving independently in a Central field which arises as a net result of the positive charge of the nucleus and the average distribution of the negative charges of the electrons. This is so called **Central Field Approximation** [3]. The state of the atom is then characterized by assigning definite n and l value to each electron. Even though the quantum mechanical validity of this description is limited, but it at least gives a starting point to the description. In this, approximation the energy depends on the charge distribution in the different electronic shells and on the quantum numbers n and l but is independent of the mutual orientation of electron orbits and spin. Latter on these effects can be introduced as *perturbation which splits the state into a number of terms corresponding to different* combinations of m_l and m_s of valence electrons [4].

The generalized Schrödinger's equation for n- electrons describing electrostatic interactions is given as

$$\sum_i \{(-\hbar^2/2m)\nabla_i^{\,2} - Ze^2/r_i) + \sum_{i>j} (e^2/r_{ij})\}\ \psi = E\,\psi \qquad \text{------------ (1.1)}$$

Where $\sum_{i>j} (e^2/r_{ij})$ represents electrostatic repulsion between two electrons separated by a distance r_{ij}.

There are no spin dependent terms in equation (1.1). The presence of this two electron operator prevents an immediate separation of the wave function into one electron functions. This repulsion is also a bit too large to be treated as a perturbation [2]. The procedure is to regroup the Hamiltonian in equation (1.1). The total effect of the attractive potential term $\sum_i -Ze^2/r_i$ is considerably reduced the central part in the repulsive term $\sum_{i>j} e^2/r_{ij}$. The procedure generally used is based on the idea of screening, according to which the greater part of the mutual repulsion terms is taken into account in the approximate solution on which a perturbation theory treatment is based. The mutual repulsion terms, being all positive, end to cancel the negative terms which represent the attraction of the nucleus. This partial cancellation is manifested as a screening, from other electrons, of the central charge by the inner electrons [2].

Let central part of $\sum_{i>j} e^2/r_{ij}$ be $\sum_i S^1(r_i)$

$$\text{Then total central potential} = \sum_i -Ze^2/r_i + S(r_i) = \sum_i u(r_i) \qquad \text{.............. (1.2)}$$

Thus we can write (1.1) as

$$H = H_0 + H_I \qquad \text{........... (1.3)}$$

Where

$$H_0 = \sum_i (-\hbar^2/2m)\nabla_i^{\,2} + u(r_i) \qquad \text{........... (1.4)}$$

and $$H_1 = \sum_{i>j} (e^2/r_{ij}) - (\sum_i Ze^2/r + u(r_i)) \qquad \text{............ (1.5)}$$

We can also introduce spin-orbit interaction

$$H_2 = \sum_i \xi(r_i)\, l_i \cdot s_i \qquad \text{.............. (1.6)}$$

The standard perturbation theory calculations can be carried out for the angular part of the solutions which give rise to angular coefficients that are functions of l and m_l and can be calculated once and for all. What is left in the diagonal matrix element of e^2/r_{12} is a set of radial integrals (called **Slater Integrals**): F^k, the direct integrals and G^k, the exchange integrals. The expressions for these integrals are given in the next section.

k extends over a small integral. It should satisfy two conditions

$$|l_1 - l_2| \le k \le |l_1 + l_2| \qquad \text{........................... (1.7)}$$

where l's are orbital angular momentum. k must also obey the condition that l_1+l_2+k = even integer [these conditions are imposed so that the coefficient in the matrix elements of e^2 should not vanish].

For F^k's the sets are (k, l_1, l_1), (k, l_2, l_2) whereas for G^k the sets are (k, l_1, l_2). Higher is k, lower are the value of F^k and G^k.

F^k and G^k have to be worked out with a knowledge of radial wave functions. Since these wave functions are not known or not expressible in a simple way, these integrals are usually not evaluated but are treated as adjustable parameters in application to the observed spectra.

The integrals appearing in the formula express the energy arising from the mutual interactions of two electrons [4].

F^k Integrals: They represent that part of the electrostatic energy which depends on the l vectors and is responsible for the separation of terms with different L- values in the LS- Coupling. e.g; in p.d configuration, the separation of ^3F, ^3D and ^3P energy terms.

G^k **Intigrals:** They give energies due to the exchange forces which depend on the spin orientations. They cause the splitting of terms with same L but different S (multiplicity) viz. ^1F and ^3F energy levels.

After they have been evaluated, spin-orbit interaction acting as perturbation gives fine structure splitting i.e $^3F_4$, $^3F_3$, $^3F_2$ levels etc. with spin-orbit interaction parameter ζ.

1.2 Cowan's approach for theoretical calculations

As described in the preceding section, the structure for two electrons system can be worked out in principle but when you deal with complex system like three electrons or even four electrons systems, it becomes almost impossible to calculate the entire structure or even to estimate the transition probabilities for the different transitions [2]. Therefore, Hartree - Fock calculations are performed with relativistic correction and correlation effects. Various computer codes have been developed for such kind of calculations like those of R.D. Cowan [5-7], C.F. Fisher [8], MCDF [9, 10] etc. The availability of fast computers with huge memory capacity has made it possible to calculate the structure to the extent of rare earth elements. For doing these calculations, various approximations are made.

The Central Field Approximation is good enough to give a good qualitative and quantitative agreement with the experiment. The basic assumption in the Central-Field Approximation is that "Each electron moves in a central, or spherically symmetrical force field produced by the nucleus and other electrons" (Slater [3]). It explains the spectrum of a neutral alkali atom in fair detail. However for the complex system the torque exerted by one electron on the other was neglected in the Central Field Model, which makes things more complicated. This model includes the electron spin and Pauli's exclusion principle, and finally the Hartree's proposal of the Self-Consistent Field method. The more successful approach by the Hartree- Fock [3] HFS Scheme) is described briefly as follows:

The time independent Schrödinger's wave equation can be written as

$$HU(r_l, \theta_l, \varphi_l) = EU(r_l, \theta_l, \varphi_l) \qquad \text{.......................... (1.8)}$$

Where E is the energy, H is the Hamiltonian and U is the wave function. The one electron hydrogenic wave function as given by Slater [3] is

$$U_{nlm_l}(r_1,\theta_1,\varphi_1)=\frac{(-1)^{(m_l+|m_l|)/2}}{\sqrt{4\pi}}\sqrt{\frac{(2l+1)(l-|m_l|)!}{(l+|m_l|)!}}R_{nl}(r)\,P^{|m_l|}(Cos\,\theta)\,e^{im_l\varphi} \qquad (1.9)$$

Where $R_{nl}(r) = P_{nl}(r)/r$ ....(1.10)

and R_{nl} or P_{nl} is normalized so that

$$\int_0^\infty [P_{nl}(r)]^2\,dr = 1 \qquad (1.11)$$

Where $P_{nl}(r)$ is the Legendre's polynomial.

Therefore, the wave function for an atom or ion with N electrons can be constructed by taking the product of wave function of its all electrons as

$$\psi_N(r_1,\theta_1,\varphi_1,r_2,\theta_2,\varphi_2.......r_N,\theta_N,\varphi_N) =$$

$$U_{n_1l_1m_{l_1}}(r_1,\theta_1,\varphi_1)U_{n_2l_2m_{l_2}}(r_2,\theta_2,\varphi_2)........U_{n_Nl_Nm_{l_N}}(r_N,\theta_N,\varphi_N) \qquad (1.12)$$

A more complete form of Hamiltonian for an atom can be written in general as:

$$H=(-\hbar^2/2m)\sum_{j=1}^{N}\nabla_j^2-\hbar^2\sum_k\frac{1}{2M_K}\nabla_k^2-e^2\sum_k\sum_j Z_k/r_{kj}+$$
$$e^2\sum_{k>L}Z_KZ_L/r_{KL}+e^2\sum_i\sum_{j>1}1/r_{ij}+H_{SS}+H_{SO}+H_{hfs}+H_{etc} \qquad (1.13)$$

Where the first term represent the K.E. of the electron involved, second that of nucleus, third the interaction between electrons and protons, fourth that between protons and fifth between the electrons. H_{ss} represents spin- spin interaction and H_{so} spin- orbit interaction. H_{hfs} is the hyperfine structure hamiltonian and H_{etc} stands for all additional effects left out so far.

Schrödinger's wave equation cannot be solved for such a complicated Hamiltonian. Therefore, the Central Field Approximation which was lacking electron spin part was modified by Hartree as **Self- Consistent Field Method** [3] where the presence of extra nuclear charge was also considered [2]. Hartree started with the wave function of the type (1.12) and Hamiltonian (1.13), simplified to the extent of retaining only the first, third and fifth terms and rendered the solution of Schrödinger's wave equation Self- Consistent through iteration. Though Hartree's wave function was symmetric, his method did not include Pauli's exclusion principle. That problem was solved by Fock by taking anti-symmetrical wave function in what is called "Hartree-Fock (HF) method (Slater [3]). The simplest wave function which satisfies the conditions of anti-symmetrization is a determinental function of the type

$$\Psi = (N!)^{-1/2} \begin{vmatrix} U_1(1) & U_1(2) & \ldots\ldots & U_1(N) \\ U_2(1) & U_2(2) & \ldots\ldots & U_2(N) \\ \cdot & \cdot & \ldots\ldots & \cdot \\ \cdot & \cdot & \ldots\ldots & \cdot \\ U_N(1) & U_N(2) & \ldots\ldots & U_N(N) \end{vmatrix} \qquad \ldots\ldots\ldots\ldots (1.14)$$

The linear combination of determinental function will also satisfy the condition.

For central field type atom, the single electron wave function is taken of the form

$$U_i(j) = \frac{1}{r_j} P(n_i l_i, r_j) S(l_i m_i \theta_j, \phi_j) \chi_j(s_j) \qquad \ldots\ldots\ldots (1.15)$$

Where P, S and χ are radial wave function, spherical harmonic and spin wave function respectively,(n_1, ℓ_1, m_l) are the quantum numbers of the wave function U and (r_j , θ_j , ϕ_j and s_j) are the radial , spherical, polar and spin coordinates of electron j.

Now solving these complicated equations was not an easy task. Scientists therefore, tried to make it practically feasible. Slater [3], Condon and Shortley [11], Froese Fischer [8] and R.D. Cowan's [5-7] contributions made it possible to calculate the structure of the atoms or the ions. The atomic energy structure is expressed in Hartree- Fock Slater theory in the form of complicated integro- differential equation. These have been simplified so as to divide the whole complex into smaller manageable integrals, called "Slater Parameters" written in the form of F^k, G^k, R^k and ζ_{nl} as discussed earlier in the beginning of this chapter. These integrals can be evaluated on rigorous theoretical basis [3,5,6,7,11] or treated simply as adjustable parameters in application to the observed spectra [2].

The Hartree-Fock method gives accurate result for light atoms, but a relativistic correction is necessary for heavy ones. The integro-differential equations involved in Hartree-Fock method are divided into smaller manageable integrals known as Slater Parameters.

Neglecting the spin-orbit interaction and magnetic effects, Slater has given the one electron energy contribution in integral form as

$$E_{av} = \int_0^\infty \left[r^{2l+2} \frac{d}{dr}\left(\frac{R^*_{nl}}{r^l}\right)\frac{d}{dr}\left(\frac{R_{nl}}{r^l}\right) - 2ZrR^*_{nl}R_{nl}\right]dr \text{........}(1.16)$$

This is called average energy. Whereas the two electrons contribution is expressed in terms of another integral

$$R^k = \int_0^\infty \int_0^\infty R^*_{n_il_i}(r_1)R^*_{n_jl_j}(r_2)R_{n_rl_r}(r_1)R_{n_tl_t}(r_2) \times \frac{2r(a)^k}{r(b)^{k+1}} r_1^2 r_2^2 dr_1 dr_2 \text{........}(1.17)$$

Where a^k and b^k are the coefficients defined by Slater.

In case of equivalent electron equation (R^k) gives the electrostatic (coulomb) part of energy in terms of symmetric integrals.

$$F^k = \int_0^\infty \int_0^\infty R^*_{n_il_i}(r_1)R^*_{n_jl_j}(r_2)R_{n_il_i}(r_1)R_{n_jl_j}(r_2) \times \frac{2r(a)^k}{r(b)^{k+1}} r_1^2 r_2^2 dr_1 dr_2 \text{..}(1.18)$$

For non equivalent electrons, the following exchange integrals are obtained;

$$G^k = \int_0^\infty \int_0^\infty R^*_{n_il_i}(r_1)R^*_{n_jl_j}(r_2)R_{n_jl_j}(r_1)R_{n_il_i}(r_2) \times \frac{2r(a)^k}{r(b)^{k+1}} r_1^2 r_2^2 dr_1 dr_2 \text{....}(1.19)$$

The integral F^k (n_l,n_l) represent that part of the electrostatic energy which depends on the orientation of the l- vectors and is responsible for the separation of terms with different L- values in LS coupling notation. Those denoted by G^k (n_l, n_l) are the exchange integrals that give energies due to the exchange forces which depend on the spin orientations; they cause the splitting of terms with equal L but different total spin S, for instance the separation of the singlet term from the triplet etc. In case of the equivalent electrons like p^2, p^3, d^2 the G^k parameters vanish. ζ_{nl} is the magnetic spin-orbit interaction responsible for the fine structure splitting.

After the expressions containing the F's and G's have been derived the magnetic spin-orbit interactions are introduced as perturbation; the expression in terms of spin-orbit integrals ζ_{nl} is

$$\zeta_{nl} = h^2 \int_0^\infty |R_{nl}|^2 \zeta(r) r^2 dr$$

$$= \frac{e^2 h^2 Z^4}{2m^2 c^2 a_0^3 n_i^3 l_i (l_i + 1/2)(l_i + 1)} \qquad (1.20)$$

Since R.D. Cowan's Code [7, 12] has been used extensively to compute the structure of the ions in the present work, its brief sketch is presented here:

The Cowan's Code is a set of four programs working in a sequence. The output from one provides the input to the other; the sequence followed is:

(i) RCN

(ii) RCN2

(iii) RCG

(iv) RCE

1.21 RCN

The Program **RCN** calculates single- configuration radial wave functions $P_{nl}(r)$ for a spherically symmetrized atom for each of any number of specified electron configurations using one of the following homogeneous differential equation approximations to the Hartree-Fock method.

(1) Hartree (H)
(2) Hartree-Fock-Slater
(3) Hartree-plus-statistical-exchange (HX)
(4) Hartree-Slater (HS)

This program can also be used for true Hartree-Fock (HF) calculations. Mostly the HX method or the centre of gravity HF method is used.

The primary input information is always written to RCN input file IN36. A typical example of RCN input file IN36 for Br IV is given in Table 1.1. This file was used to calculate the spectra of trebly ionized bromine (Br IV). In addition to the radial wave functions, also calculated for each configuration are various radial integrals R^k, F^k, G^k, ζ and total energy of the atom E_{av} for each configuration involved in the calculations. Approximate relativistic and correlation energy corrections are incorporated in these calculations by this program.

1.22 RCN2

RCN2 is the next program of this sequence. This program takes the output of RCN program as input and prepares a complete file of input data for program RCG for the calculations of energy levels and spectra of an atom. Thus it is an interface program.

The **RCN2** accepts radial wavefunctions for one or more different configurations of one or more atoms or ions from RCN and then calculates various multiple – configuration radial integrals, overlap integrals, $< P|P^1 >$; configuration interaction coulomb integrals R^k, the spin-orbit interaction integrals $\zeta_{nl,}$ the radial electric- dipole and the electric- quadrupole integrals. In its most commonly used option, it automatically computes all quantities required for calculating the energy levels and the spectra of an atom. It scales all energy-level-structure parameters F^k, G^k, R^k, and ξ.

1.23 RCG

The program **RCG,** computes the angular factor of various matrix elements in the theory of Atomic Spectra [7]. This program employs Racah- algebra techniques and the input contains the coefficients of the fractional parentage (cfp) for each subshell l^w involved in the electron configurations [2].

$$(n_1\, l_1)^{w1}\ (n_2 l_2)^{w2} \text{-------------------------} (n_q\, l_q)^{wq} \qquad \ldots\ldots\ldots\, (1.21)$$

The angular factors are:

(i) Coefficients of unit matrix E_{av}, the centre of gravity of each configuration.

(ii) The coefficients f_k, g_k, and d of the single configuration direct and exchange Coulomb interaction (F^k and G^k) and spin-orbit interaction ζ radial integrals and the coefficient r_d^k and r_e^k of the direct and exchange configuration interaction coulomb radial integrals R^k which are involved in the calculation of the Hamiltonian (energy level) matrix elements.

(iii) The magnetic- dipole matrix elements and the angular coefficients of the electric- dipole and electric- quadrupole reduced matrix elements;

$$P_{ll} = < l \; \| r^t \| \; l > \qquad \text{............ (1.22)}$$

also possible are angular coefficients of certain effective- coulomb interaction operators α, β, γ, T, T_1 and T_2 and "illegal – k" operators F^k and G^k used in representing weak configuration- interaction effects [2]. If numerical values of the radial integrals E_{av}, G^k, F^k, ζ, R^k are provided, energy levels and intermediate-coupling eigenvectors are computed. If numerical values of the electric dipole integrals are supplied, then the energy levels and eigenvectors are used to compute the spectrum line, wavelengths, and the associated oscillator strengths and radiative transition probabilities. Usually all these inputs are automatically provided by the program RCN2.

RCG can also calculate the photo ionization cross sections, autoionization transition probabilities and plane wave Born electron impact collision strength [3].

1.24 RCE

RCE is the least squares fitting programs. When sufficient numbers of energy levels are established then these experimental levels are used to adjust the Slater Parameters according to the experimental levels. The unknown levels are then predicted more precisely and become easier to establish.

The fitting process is carried out by an automatic iterative procedure until the parameters values no longer change from one iteration cycle to the next by more than 0.03 cm^{-1} or so, for a specified maximum number of cycles [2]. The iteration can be carried out in any one of the seven angular- momentum coupling schemes available in RCG program. Final eigen vectors are printed in the desired representation. Finally when all or most of the levels are experimentally known, the fitted parameters are used back in RCG to recalculate the transition probability or radiative life time, energy eigen values etc. It has been noticed that the observed intensities are fairly in good agreement when least squares fitted parameters are used for calculations.

Table 1.1: Input file for the program RCN to calculate the structure of Br IV.

Z	Spectrum	Configuration	
35	4Br4	s24p2	3D10 4S2 4P2
35	4Br4	s24p5p	3D10 4S2 4P1 5P
35	4Br4	s24p6p	3D10 4S2 4P1 6P
35	4Br4	s24p4f	3D10 4S2 4P1 4F
35	4Br4	s24p5f	3D10 4S2 4P1 5F
35	4Br4	sp24d	3D10 4S1 4P2 4D
35	4Br4	sp25s	3D10 4S1 4P2 5S
35	4Br4	4p4	3D10 4P4
35	4Br4	sp3	3D10 4S1 4P3
35	4Br4	s24p4d	3D10 4S2 4P1 4D
35	4Br4	s24p5d	3D10 4S2 4P1 5D
35	4Br4	s24p6d	3D10 4S2 4P1 6D
35	4Br4	s24p7d	3D10 4S2 4P1 7D
35	4Br4	s24p5s	3D10 4S2 4P1 5S
35	4Br4	s24p6s	3D10 4S2 4P1 6S
35	4Br4	s24p7s	3D10 4S2 4P1 7S
35	4Br4	s24p8s	3D10 4S2 4P1 8S
35	4Br4	sp25p	3D10 4S1 4P2 5P
35	4Br4	sp24f	3D10 4S1 4P2 4F
35	4Br4	p34d	3D10 4P3 4D
35	4Br4	p35s	3D10 4P3 5S
35	4Br4	s24p5g	3D10 4S2 4P1 5G
35	4Br4	sp4d2	3D10 4S1 4P1 4D2
35	4Br4	sp5s2	3D10 4S1 4P1 5S2
-1			

1.3 Transition probability

The spontaneous Transition probability per unit time [7] from an excited state to a state of lower energy

$$a = \frac{64\pi^2 e^2 a_0^2 \sigma^3}{3h} \sum_q \left| \left\langle \gamma' J' M' \left| P_q^{(1)} \right| \gamma J M \right\rangle \right|^2 \qquad (1.23)$$

where; a_0 - Bohr radius, σ - wave number and

$$P_q^{(1)} = \sum_{i=1}^{N} r_q^{(1)}(i) = \sum r_i c_q^{(1)}(i) \qquad (1.24)$$

is the q^{th} component of classical dipole moment of the atom in units of $-e\,a_0$.

The total Transition probability from a state $\gamma' J' M'$ to all M states of γJ is

$$A = \frac{64\pi^2 e^2 a_0^2 \sigma^3}{3h(2J'+1)} S \qquad (1.25)$$

and the weighted transition probability is

$$gA = (2J' + 1)A = \frac{64\pi^2 e^2 a_0^2 \sigma^3}{3h} S \quad \text{......................} (1.26)$$

where g is the statical weight of the upper level and

$$S = \left|\left\langle \gamma' J' M' \left| P_q^{(1)} \right| \gamma J M \right\rangle\right|^2 \quad \text{...} (1.27)$$

The quantity S is a measure of total strength of the spectrum line including all possible transitions *M,M'* [7].

1.4 Oscillator strength

The total probability of emission [7] from a specific state of the upper level j to all (2J+1) states of the lower level i is given by

$$f_{ji} = -\frac{8\pi^2 m a_0^2 c\sigma}{3h(2J' + 1)} S \quad \text{..} (1.28)$$

and the weighted oscillator strength is given by

$$gf = -(2J + 1) f_{ji} \quad \text{...} (1.29)$$

Where g refers to the weight of the lower level.

1.5 Isoelectronic sequence

A term isoelectronic sequence used in spectroscopy to designate the set of spectra produced by different chemical elements ionized in such a way that their atoms or ions contain the same number of electrons. Such a sequence generally starts with any element of the periodic table and is followed by other elements in the order of their atomic number. For example Zn I, Ga II, Ge III, As IV, Se V, Br VI etc. All members of this sequence have one extra nuclear charge from their preceding member. All these elements are made to have the same number of electrons as neutral zinc has by stripping one electron from gallium, giving singly ionized gallium Ga II; two electrons from germanium, giving doubly ionized germanium Ge III etc. The number written after the symbol of element is called spectrum number and is denoted by ζ. This number ζ representing the net charge of the core given by $\zeta = Z - (N - 1)$ where Z is the atomic number and N is the total number of extra nuclear electrons. For example $\zeta = 1$ for neutral zinc; Zn I, $\zeta = 2$ for Ga II; $\zeta = 3$ for Ge III and so on for other members and elements. In general a sequence is named on it's first member; however, if emphasis is on a particular member of the sequence than the sequence might be denoted by that particular member e.g. Zn I sequence may be called as Br VI sequence. Similarly we can take another example as Br IV sequence is also called Ge I isoelectronic sequence and for this $\zeta = 1$ for neutral germanium Ge I; $\zeta = 2$ for As II; $\zeta = 3$ for Se III, and so on for other members and elements. The isoelectronic plot for Hartree-Fock values of Br IV isoelectronic sequence is given in Fig 1.1.

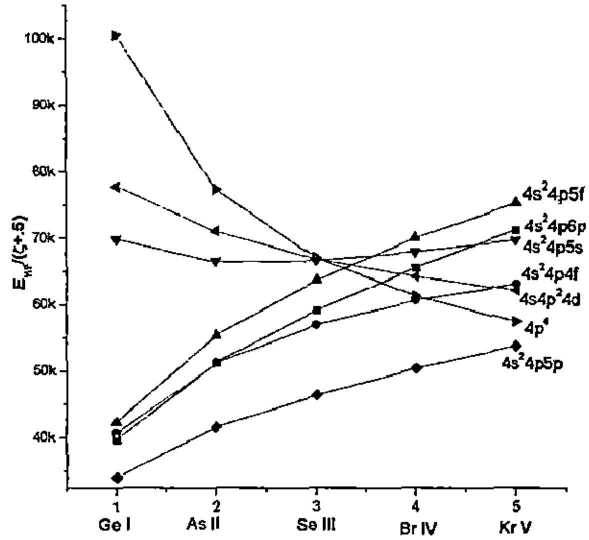

Fig 1.1: Extrapolation for Br IV isoelectronic sequence

As each member of the isoelectronic sequence have same number of extra nuclear electrons, the energy levels and the spectrum lines arising from each atom/ion will show remarkable similarities [1]. Such atomic systems exhibit a number of relationships that are of great interest both for the practical analysis of spectra and for the systematic description of the experimental results and their extrapolation. The regularity of any observed level found in different members of the sequence can be checked by employing various methods.

Graphical methods are of great help in this regard and they provide a broad survey and are helpful in these studies. When term value i.e. the energy value of a level in the unit of cm^{-1} is plotted against Z, we obtain steeping upwards trend since energy increases rapidly with Z. Such plots are not sufficiently sensitive to show irregularities. Prof. Bengt Edlen [4] solved this problem during his studies of various atomic irregularities along such isoelectronic sequences. The term value and some function of the term value as for instance $\sqrt{T}$, $T/(\zeta + c)$, $T/(\varsigma+c)^2$, etc. may be plotted against ζ, here c is a suitably chosen constant. The most convenient and useful expression, out of them is $T/(\varsigma + c)$ or $E/(\varsigma + c)$. It gives a linear wave number scale for each spectrum and permits a free choice of zero level. These curves further can be made horizontal and smooth by choosing an appropriate value of the constant c. The value of this constant may be guessed from the equation $E_1/(\varsigma_1 + c) = E_2/(\varsigma_2 + c)$ where E_1 is the energy of lower member of the isoelectronic sequence and E_2 is the energy of the higher member. This constant is more effective for the starting members of the sequence than for higher members.

For the terms with equal n value such graphs are nearly parallel lines which gives another opportunity of plotting the quantity $(\Delta E - \Delta L)/\varsigma$, where ΔE is the difference between a given level E and a references level E_0, and ΔL is the difference between the limits L and L_0 for E and E_0 respectively. This allows a larger scale and hence a more accurate and detailed comparison. Thus the linear relationships exhibited by these graphs allow a convenient interpolation and extrapolation.

For the transitions involving configurations with different n values, the isoelectronic relations can be written in a form similar to the screening doublets. Here $E/(\varsigma + c)$ vs ζ curves give upward moving trends for higher member of the sequence. In the analysis of extended isoelectronic sequences we may plot $E/(\varsigma + c) - \sigma^H \varsigma$ against ζ, where c is a constant and σ^H is the hydrogenic term given by the following relation

$$\sigma^H = R\varsigma^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad \text{......................... (1.30)}$$

where R is the Rydberg constant, n_1 and n_2 are principal quantum numbers of the ground and the other shell involved in the configuration concerned, respectively. The above expression can be written more precisely as

$$\sigma^H = \frac{R\varsigma^2}{n^2}\{1 + \frac{\alpha^2\varsigma^2}{n^2}\left(\frac{n}{l+1/2} - \frac{3}{4}\right) \text{.........................(1.31)}$$

where α is the Sommerfeld fine structure constant and n and l are the orbital quantum number of the other electron.

As mentioned earlier, there are many other ways to check the regularities in the isoelectronic sequence using either isoelectronic extrapolation or interpolation. Regularities in the energy parameters like F^k, G^k, etc. and other physical quantities, associated with atoms and ions like electron affinities can also be checked employing these techniques. Further details on isoelectronic sequence can be found in reference [4].

1.6 Term values and Rydberg series

Regularity in the distribution of lines in atomic spectra was known from very beginning. The intervals between successive lines, and their intensities, decrease in a more or less regular way towards shorter wavelengths, so as to make the series converge towards a definite limit [4].

The wave-number of any line in the spectrum is given by

$$\sigma = \frac{R}{n_0^2} - \frac{R}{n^2} \qquad (1.32)$$

where n_0 and n may take any integral value such that $n_0<n$. Each value of n_0 gives rise to a series with an infinite number of lines approaching the limit R/n_0^2 and such series is called Rydberg series. The series limits corresponding to different values of n_o form in turn an infinite series of terms approaching zero, the ionization limit. This series of terms also constitutes a Rydberg series, and can be taken into account by writing their term values empirically as

$$T_n = \frac{R\zeta^2}{n^{*2}} \qquad (1.33)$$

Where $n^* = n - \delta$. here n^* is called as effective (principal) quantum number and δ is the quantum defect. Quantum defect δ takes different value for each series. The quantum defect δ is due partly to penetration into the core and partly to a polarization of the core in the field of outer electron [4]. The effect of penetration is dominating for smaller l value while polarization alone is responsible for it at larger l values.

If E is the relative term value counted upwards from the ground term, and E_l is the value of series limit on the same scale then the absolute term value is defined as

$$T = E_l - E \qquad (1.34)$$

The ionization potential (I.P.), difference between the uppermost and the lower most term can be related as

$$I.P. = E_l = T + E \qquad (1.35)$$

The quantum defect and hence the effective quantum number can be determined using the Ritz formula. For it an accurate value of the series limit of the term system is necessary [1].

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CHAPTER 2

Experimental Details

In this chapter we discuss the details of the light sources, spectrographs and the photographic plates used in recording the spectrum of bromine, the procedure adopted in obtaining the wavelengths list in the 150-2000Å wavelength region. This list of transition lines was supplemented by another list prepared elsewhere to extend the wavelength region up to 4600Å. The separation of various ionization lines appearing on the spectrograms have also been discussed.

2.1 Light sources or sources of radiant energy

In a light source, individual atoms or molecules, usually in the vapour or gaseous state, emit radiation, whenever they receive an excess amount of energy. The various excitation sources that are conventionally used for obtaining the line spectra of chemical elements differ in the technique by which energy is supplied to the atoms and molecules. They may receive energy by absorption of radiation, by thermal excitation, by transforming kinetic energy through inelastic collisions with electrons and atoms, by electric currents etc. Flame, arc, spark, discharge at low pressure (high frequency discharge, hollow-cathode discharge and vacuum spark discharge), radio frequency torches, plasma jets and laser produced plasma are different light sources that have been used in spectroscopy. In fluorescent spectra, radiation of suitable frequency is used while in flame and furnace spectra, the energy is supplied thermally to the atoms or molecules of the system [1].

According to the radiation emitted by the different light sources, they are classified as continuous or discontinuous, although the distinctions between the two are not very sharp. A continuous spectrum is characterized by a generally uninterrupted range of wavelengths over a considerable region, and by the absence of sharp lines or bands [2]. For example in the visible region such spectrum appears as an unbroken series of colors changing imperceptibly from one to the next. Contrary to this, the spectrum of discontinuous source shows a number of sharp, narrow bright lines. The details of various light sources can be found in the ref [2,3]. The light sources, which are capable of operating in high vacuum, and whose excitations are adequate enough to produce the desired high frequency radiation, are suitable for ultraviolet region e.g. the vacuum spark source [1]. The bromine plates, used for the present analysis of different spectra of bromine ions (Br III-VI), were recorded using the triggered spark and sliding spark light sources. These two sources are briefly described here in addition to an introduction of electric spark.

2.11 The Electric spark

The electric spark is an electrical discharge across a gap separating two electrodes between which a high potential difference exists. The potential gradient necessary to initiate such a discharge depends on the gas pressure in the gap, the ionization potential of the gas, the shape of the electrodes and other factors [3].

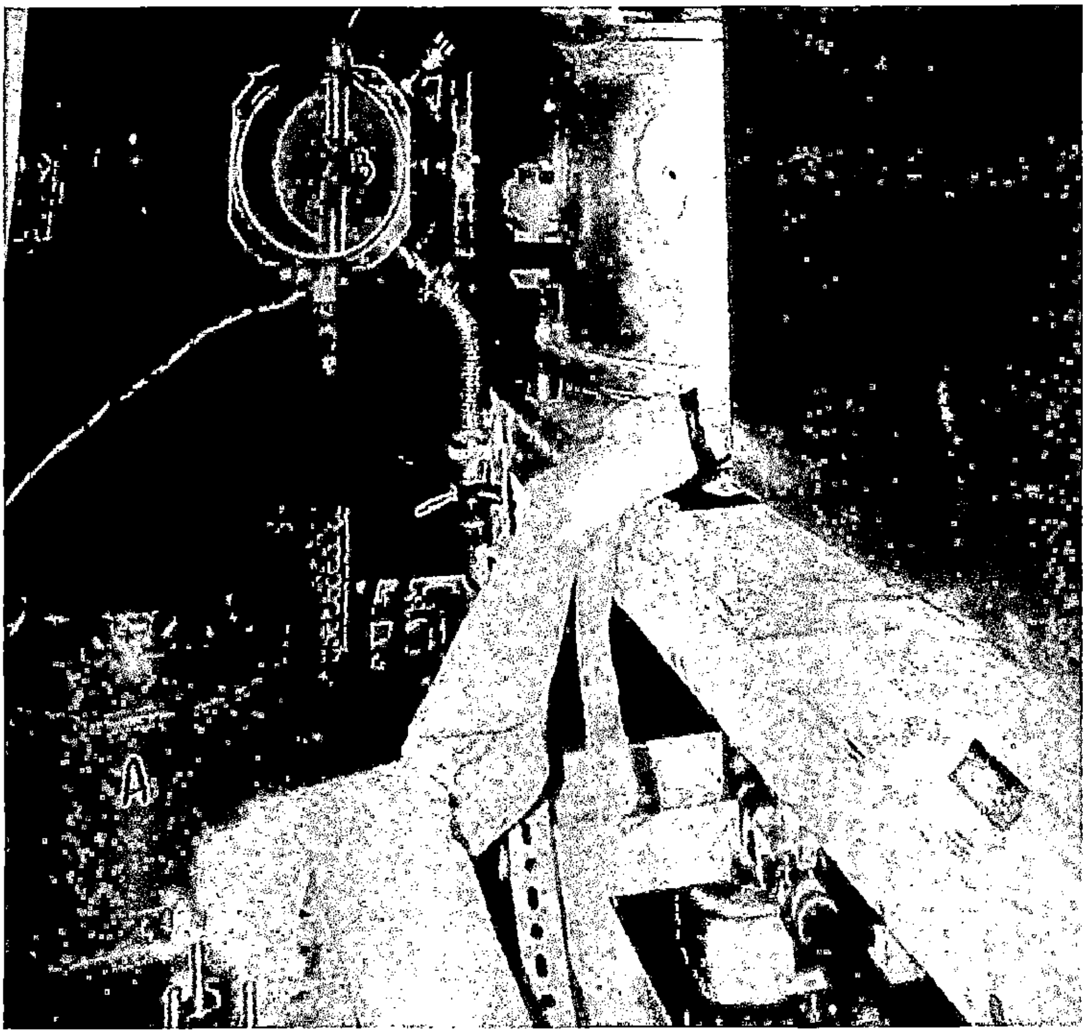

Fig. 2.1: A: Inductance coil, B: Vacuum spark chamber and C: The slit valve

This light source produces higher excitation and has greater flexibility in power and control. In the electrical circuit, spark is produced by connecting the secondary of a transformer across an insulated electrode holder which carries the test sample [2]. In most cases a capacitor is also connected across the secondary of transformer to increase the discharge current. The transformer, used, must have a size adequate to charge the condenser up to the expected voltage while the condenser may be of almost any size. High voltage or large value of condenser gives rise to the higher excitation of the atoms of the material of electrodes. An inductance [see Fig 2.1] is also used in the spark circuit as it decreases the initial current and degree of excitation in the spark. The variation of inductance separates the spectral lines from the different ionization stages. Sparks are operated at higher electrode temperatures and higher current densities [3].

2.12 Triggered spark light source

The spectra of bromine were recorded by using triggered spark light source. It is a modified spark light source with better control over sparks in the voltage range 2 kV to 20 kV [1]. A 14.5 μF fast charging low inductance capacitor, chargeable up to 20 kV is used. To obtain higher ionization stages a parallel combination of these 14.5 μF capacitors or a big condenser bank of 120 μF is used. A trigger module TM-11 A is used to initiate the discharge in triggered spark gaps and to regulate the voltage. TM-11 A is a compact versatile instrument made to provide a high voltage trigger pulse of fast rise time. It provides a trigger pulse of 30 kV. TM-11 A consists of a line voltage to D.C. power supply, a krypton switch tube, a primary triggering circuit and a pulse output transformer. The output is provided through ceramic high voltage bushings at the back side of cabinet. These bushings also provide limited d-c isolation between the ground of the cabinet and the pulse output. An sketch of the Triggered spark source is shown in Fig. 2.2.

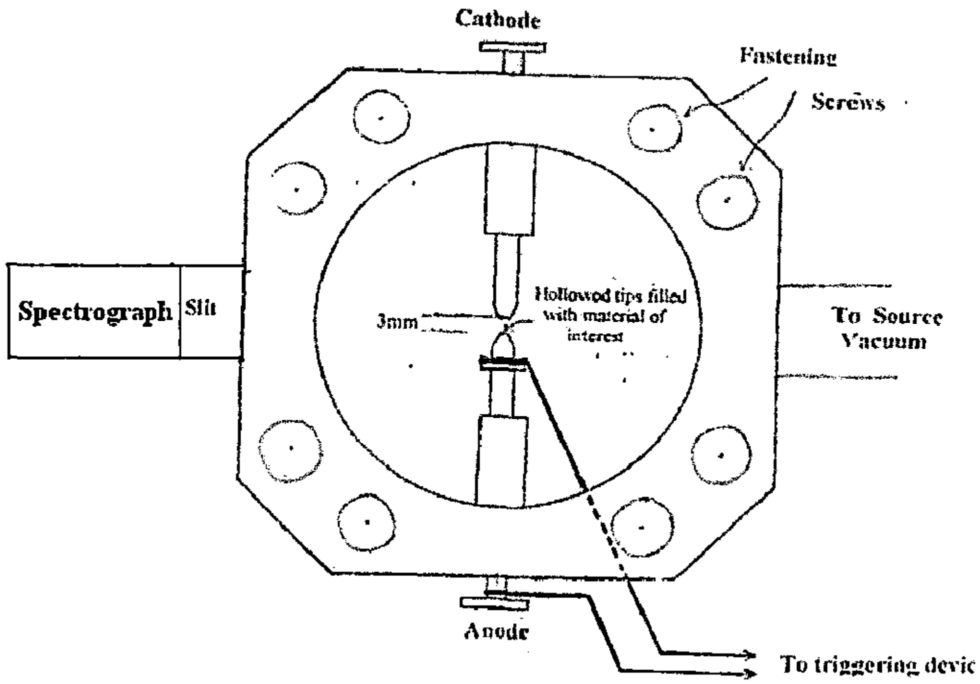

Fig. 2.2: Triggered spark

2.13 Sliding spark light source

In the sliding spark source a suitable spacer is introduced between the two electrodes. Here spark slides through the spacer. This source operates at low voltages but very high current. Fast-charging capacitors are used to discharge through electrodes. The spark is controlled by a motor which works like a circuit breaker. This motor has an attachment which rotates in a gap in the circuit and completes the circuit for a brief interval at the peak voltage of each half cycle. During this period discharge takes place [1]. Before the next fit of gap the capacitor charges again and thus the cycle continues. The peak current in the discharge ranges from 200 amperes to 3000 amperes or even more in certain cases. The exposure time is reciprocal to the discharge current, for low currents like 200-300 amperes it may be an hour or more and for high currents approximate to 1000 amperes it may be of a few tens of minutes (say 30 minutes). The variation of peak current gives a reliable ionization separation. Different exposures are taken at different peak currents. Spectra of low ionized atoms are obtained at low currents like 200-300 amperes with charging potential less than 1kV and that of moderately (five or six times) ionized atoms, current of range 800-1200 amperes are suitable. The spectra of even higher ionized atoms are obtained at much higher currents, ranges up to 4000 amps. In no case the charging potential exceeds by 2 kV. The ionizations achieved in the sliding spark source are lower than in triggered spark light source but the spectral lines are much sharper. The circuit diagram for a sliding spark source is shown in Fig 2.3.

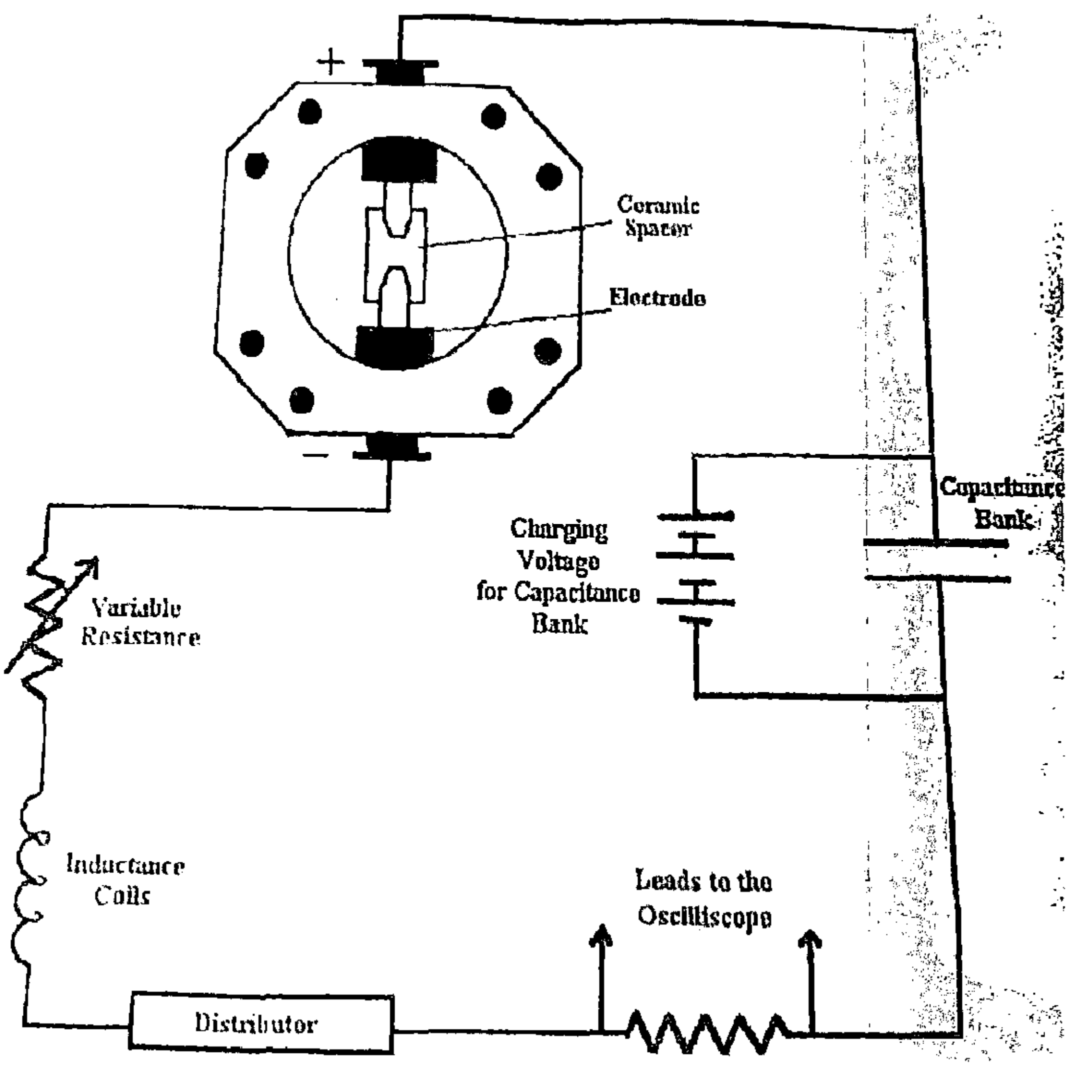

Fig. 2.3: Sliding spark circuit

2.2 Spectrograph

An instrument that can be used to produce a spectrogram, a photographic image of a spectrum, is called spectrograph [2,3]. It is a powerful tool for the investigation of the properties, nature, composition, and character of the material emitting the radiation, and for determining the structure of the absorbing and radiating atoms, ions or molecules. The spectrograph, generally, consists of a dispersing device, an optical system, and an entrance aperture. An important characteristic of any spectrograph is its dispersion, or power to spread different wavelengths out so that they emerge from the dispersing system at different angles and are focused in different positions in the focal plane of the spectrograph. Depending on dispersing device; spectrographs are categorized in two groups i.e. prism spectrographs and grating spectrographs [1].

The selection of a spectrograph depends on different factors e.g. the wavelength range over which it can be used, the extent of its dispersion and its variation with the wavelength, the brightness of the spectrum, the resolving power of the instrument etc. The diffraction grating spectrographs have broader spectral coverage, greater dispersion and resolving power per unit cost, greater light transmission in certain cases, greater uniformity of dispersion, and greater freedom from scattered light in comparison with prism spectrographs [3]. The actual limit of the wavelength attained by any optical instrument depends not only on the angle of incidence but also on the light source, exposure, photographic plates etc. In the low wavelength region, grazing incidence spectrograph is a better choice which can record spectrum up to a few angstroms while in the longer wavelength region (greater than 300 Å), normal incidence spectrographs are used. Medium quartz, constant deviation, three prism etc. are the low dispersion spectrographs used to record the spectrum in visible region. Various spectrographs [2-4] are available for recording of spectrum in air at different spectroscopic laboratories e.g. 1.5 m, 35 feet and 21 feet grating spectrographs are present in our spectroscopy laboratory at Aligarh Muslim University. 3-m normal incidence vacuum spectrographs at Moscow, Antigonish, Swedan, Aligarh etc. and 10.7-m spectrograph at NIST are grating spectrographs with better resolution used to record the spectrograms in high vacuum [1].

In the present investigation most of the data was covered in vacuum ultraviolet wavelength region and therefore we have made use of both grazing incidence and normal incidence spectrograph. The brief description of these two spectrographs is given in the following section.

2.21 Normal incidence vacuum spectrograph

All the data in the wavelength region 300 – 2000 Å used in our work is based on the plates which were recorded on a 3-m normal incidence vacuum spectrograph [Fig. 2.4] at St. Francis Xavier University, Antigonish (Canada). Therefore we will describe here the main features of 3-m normal incidence spectrograph [1] set up of the Antigonish laboratory. The Antigonish spectrograph is made of cylindrical chamber of about 30 inches inner diameter. The vacuum tank is made of aluminum sheets bolted together with rubber gaskets in grooves along the joints. The top and bottom sheets are supported by vertical thick aluminum plates. These vertical plates prevent the deformation of top and bottom sheets during the evacuation of vacuum tank. These aluminum plates are supplied with suitable apertures for the passage of light. The optical instruments, that is, slit, grating and plate holder are mounted on a rigid frame formed by the tank. The slit is mounted on the end wall besides the plate holder tank. This slit can be accessed through a stop cock at atmospheric pressure; however it can be removed without disturbing the vacuum of the tank. The slit can be visually inspected during exposure through a window in the vacuum tank wall at a position which allows the zero-order light beam to emerge. The length of the slit is 3 mm and its width is set about 20-25 microns by using aluminum foils strips of known thickness. The mounting of grating can be adjusted by different screws provided to turn and tilt it about specific axes and to focus it. All these three parts can be accessed when the casing of grating is opened. The Antigonish normal incidence spectrograph is equipped with an holographic osmium-coated grating having 2400 lines/mm over a ruled surface of 65x150 mm^2. It is blazed at 1200Å and gives a plate factor of 1.385 Å /mm in the first order of dispersion which remains almost constant in the entire region. The plate holder is designed in such a way that it forms a Rowland circle matching the radius of curvature of plate holder. The plate holder can be moved in a direction perpendicular to the plane of Rowland circle even when the instrument is evacuated. Due to this motion of plate holder, it can be adjusted in different positions, which gives a chance to take several exposures without disturbing the vacuum. But during loading and unloading of the plate the vacuum of the chamber is destroyed. The length of the plate holder is about 760 mm, either three 10 inches or two 15 inches long plates can easily be fitted against the circularly cylindrical surface of the plate holder. Spark chamber is arranged in a way so that spark gap between the electrodes is exactly in front of the slit. Some time He-Ne laser is used to achieve the perfect alignment of electrode gap with the slit. There are various valve provided to prevent the vacuum of different chambers. Oil diffusion pump and backing pump are used to evacuate the chamber. The pump system evacuates the spectrograph to a pressure of 10^{-5} to 10^{-6} torr after five to six hours of pumping.

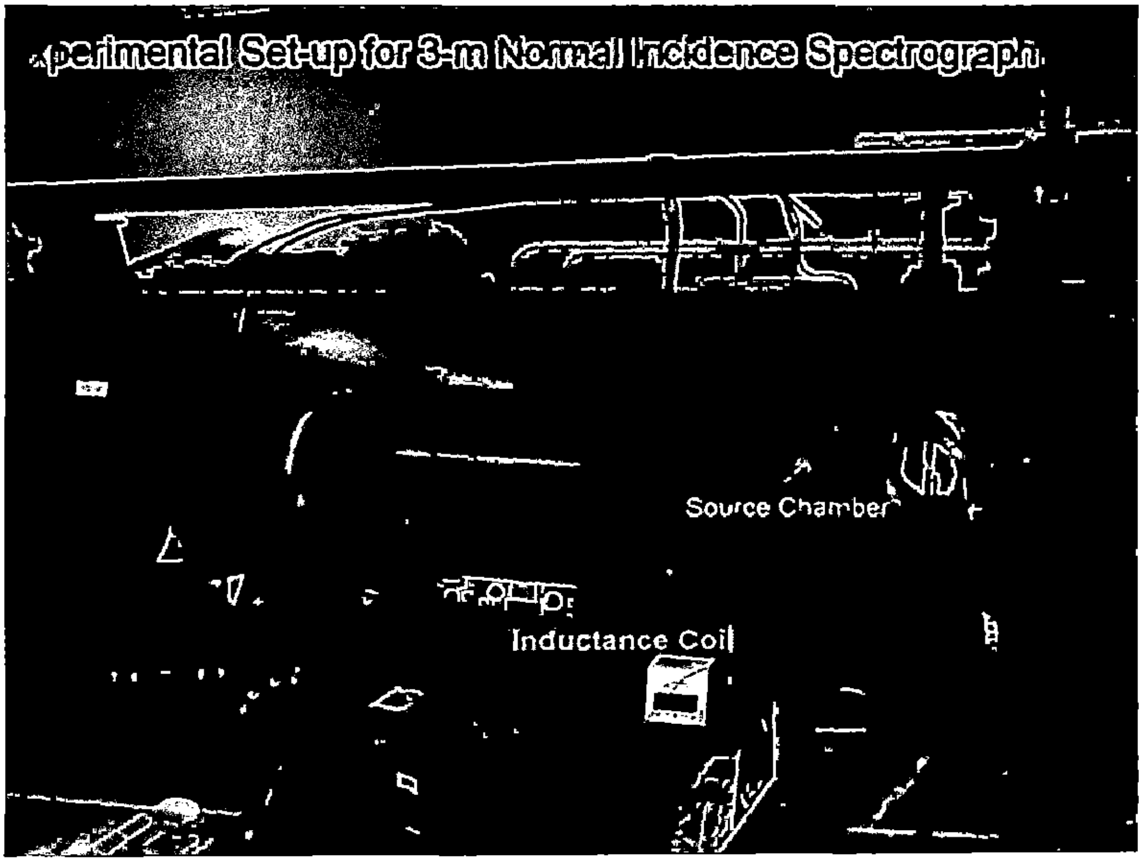

Fig. 2.4: Experimental setup for 3-m Normal incidence spectrograph

The light from the source passes through horizontal slit and falls on the grating and diffracted light is received on the photographic plate. By changing the orientation of grating the angle of incidence can be varied which subsequently changes the wavelength region covered. The region of wavelength 300 – 1240 Å was covered in first set-up at an angle of incidence about 10^0 while in second set-up the angle of incidence was about 18^0 covering the wavelength region 1040 – 2080 Å. These two set-ups of recording give an overlapping region of about 200 Å to normalize the intensities and to establish the correspondence for characteristics of ionization separation. Further details of a similar 3-m normal incidence vacuum ultraviolet

(VUV) spectrograph can be found in ref [5] and [6] respectively. The experimental setup for 3-m normal incidence spectrograph and an schematic diagram of it are shown in Figs 2.4 and 2.5 respectively.

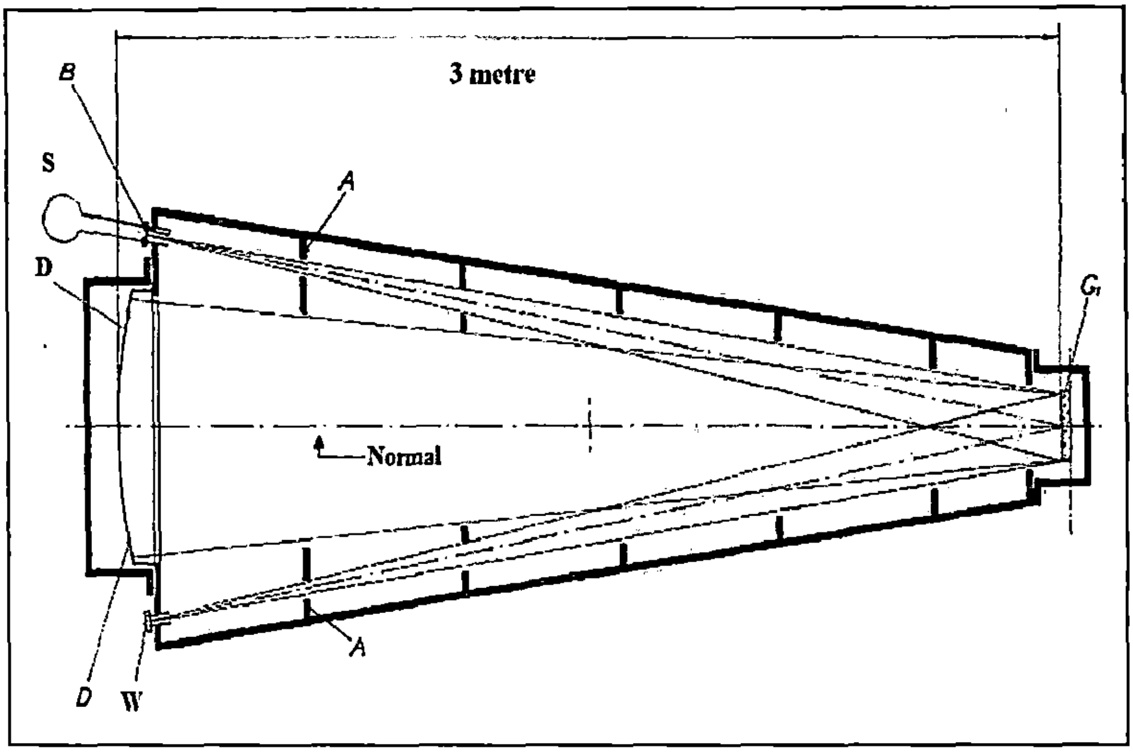

Fig. 2.5: Schematic diagram of 3-metre normal-incidence spectrograph Parts: supports (A-A), ource (S), slit (B), grating (G), plate holder (D-D), zero order window (W)

2.22 Grazing incidence spectrograph

The reflectivity of all grating materials decreases with the decrease in wavelength and it becomes very low for the wavelength shorter than 300 Å, therefore even strong lines are not recorded by normal-incidence spectrograph set-up. This problem of normal-incidence set-up is solved by using grazing-incidence spectrographs [1]. In this type of spectrograph, high angles of incidence on the grating are used so that the light striking nearly tangentially on the grating surface undergoes total-reflection. A diagram of the concave-grating mounting with high angle of incidence, focused along the Rowland circle is shown in Fig. 2.6 [2]. Different angles of incidence have been used in this type of spectrograph. The selection of angle depends on the wavelength range to be investigated and its dependency can be seen from the formula for critical angle [2],

$$\sin\,\theta_c = (e/c)\lambda\sqrt{(N/\pi m)} \qquad \text{.............................} \quad (2.1)$$

where, e and m are charge and the mass of the electron; c is velocity of light; N is the number of electrons per unit volume; $\theta = 90\text{-}\alpha$, α is the angle of incidence and λ is the wave-length above which there is critical reflection.

Since sin θ is proportional to λ, the shortest wave-length that can be obtained are 320Å, 160Å, 75Å, and 53Å for angles of incidence of 0°, 60°, 80°, and 85.6° respectively if other conditions being comparable [2,3]. With increase in the angle of incidence, the astigmatism of the grating increases rapidly. At the same time the effect of the finite width of the grating and the length of the rulings becomes significant. The dispersion of the grazing-incidence spectrographs is much larger than that of the normal-incidence types and varies much more rapidly with wavelength. The resolving power of the grating decreases with the increase in angle therefore to maintain this; the optimum width is much smaller than the usual grating mounts.

Over the range in which both normal-incidence and grazing-incidence grating spectrographs are useful, the selection between the two types depends upon the application. If the weakest lines are to be observed, the greater reflecting power at grazing-incidence favors the use of an instrument of the grazing-incidence type and if precise wavelength is required, the nearly normal dispersion and greater freedom from aberrations in the normal-incidence type may be of advantage [1].

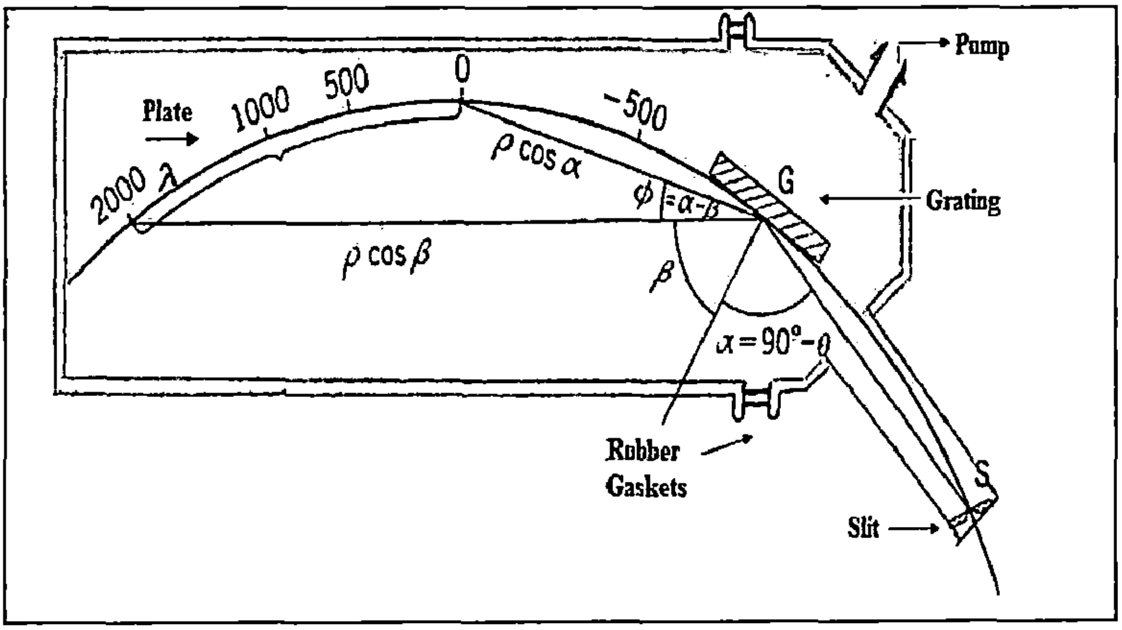

Fig. 2.6: Schematic diagram of grazing-incidence spectrograph

2.3 Recording of the bromine spectrum:

All the data (300Å – 2080Å) used in our work is based on the plates which were recorded on a 3-m normal incidence vacuum spectrograph [Fig 2.4] at the Department of Physics, St. Francis Xavier University, Antigonish, Canada. As mentioned earlier, the spectrograph was equipped with 2400 lines per mm osmium coated concave grating blazed at 1200 Å, having an inverse dispersion of 1.385Å mm^{-1}. A triggered spark was used as excitation source, where high-purity LiBr or NaBr was packed into the cavity of aluminium electrodes. The charging system consisted of a 14.5μF low inductance capacitor. The charging potential was varied between 2 and 6 kV. Series inductance was also used to vary the excitation conditions to separate out lines of various ionization stages. At low voltage discharges with series inductance coil, lines of higher ionization were eliminated on the track. However, they favored the higher excitation as the charging potential was increased. In the shorter wavelength region (below 300Å), the above mentioned data were supplemented by the data which was recorded by Joshi and Van Kleef [7] on a 6.65-m grazing incidence spectrograph with an inverse dispersion of 0.46 mm^{-1} at the Zeeman laboratory in Amsterdam. The sources used in this case were a triggered spark and a sliding spark both where LiBr powder was packed into the cavity of Al electrode which was made a cathode or an anode. The exposures were taken on Kodak plates. The above data in the higher wavelength region were also supplemented by an extended line list above 2000 Å by Budhiraja [8] based on recording made at St. Francis Xavier University, Antigonish (Canada).

2.31 Photographic plates and recording procedure:

The spectra of bromine were photographed on two types of photographic plates viz. Kodak SWR (short-wave radiation) and Kodak 101 – 105 plates. The latter are a few times more sensitive in the wavelength region below 400Å and consequently need lesser number of shots for the adequate development of the spectra. After recording both types of plates were developed in D-19 developer, and fixed in F-5 Kodak rapid fixer. However, the procedure of the development is different for the two types of the plates [9]. For the SWR (short-wave radiation) plates, the temperature of the developer and fixer was about 20°C and development time was two to three minutes. The Kodak 101 – 105 plates were soaked in chilled water for 10-15 minutes and then developed in chilled developer for about 3 minutes. For the better development the plates were moved in the developer all the time. The fixing time was 15-20 minutes for both the plates. After fixing, the plates were put in a water tank with water flowing in it. To dry a plate, it is held against the wall for 30-40 minutes. Once dried the plate is marked with an identification number [9].

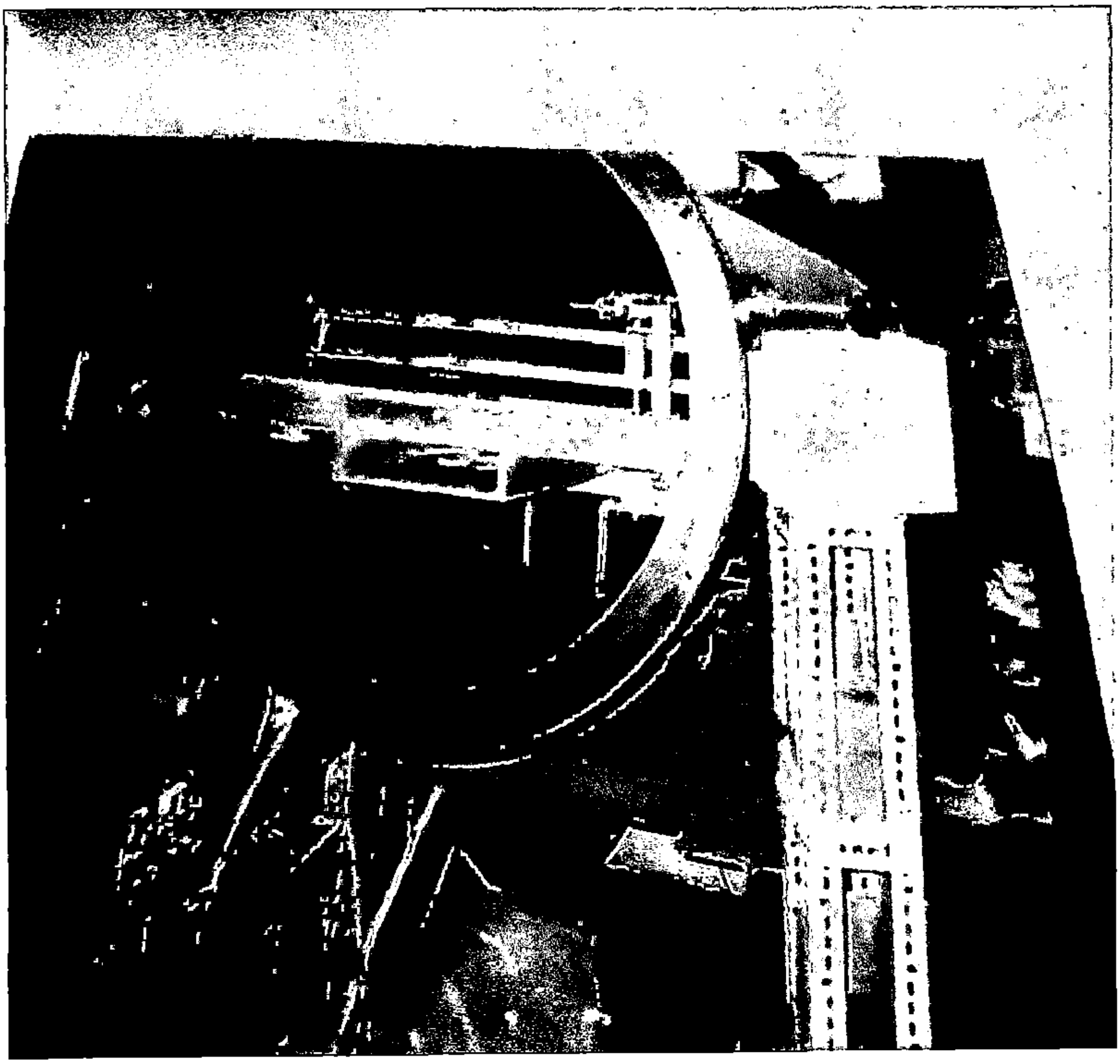

Fig. 2.7: A – A': Plate holder

2.32 Reduction of the spectrograms (or preparation of the line list):

The position and intensity of each spectral line on the plate was measured using Zeiss Abbe Comparator in our laboratory of the Department of Physics, Aligarh University. This comparator can measure the line list position for sharp lines to 0.0005 mm (equivalent to 0.0001Å) and a few times larger for wide lines and asymmetric lines. The line intensities are the relative visual darkening of the lines. These relative values are valid over a short distance on the plate. The other parameters also recorded for each line are the line shape and character viz, whether it is a normal line, wide line, diffused line, shoulder line, asymmetric line, or line with polarity (short lines); it is indicated by numeric value 1-9; 1 character indicated for normal line, 2 for broad, 3 for doubtful, 4 for wide line, 5 & 6 for polar line, 7 for shoulder line and 8 & 9 for asymmetric lines. These characters were given with special attention to the spectra recorded on grazing incidence spectrograph and measured on grant comparator. Often more than one track on a plate has been measured. The line of oxygen, carbon, nitrogen, and aluminum also appear on the plate due to the air present in the evacuated source chamber and due to the Al electrodes. They are identified on the plate as well as on the measurement list.

The exposure taken on the grazing incidence spectrograph was also measured on semiautomatic comparator COSPINSCA at the Zeeman laboratory. The carbon, oxygen and aluminum lines [10,11] present as impurities were used as internal standards to calibrate the spectrum with a polynomial fit program.

The wavelengths of the lines corresponding to the measurement are calibrated with a polynomial fit program using 3-4 degrees of freedom for the normal incidence wavelength region and 8-9 degrees for grazing incidence by the computer program "**Mosfit**" developed by G.J. Van Het Hof of Amsterdam [12]. This program in principle is a polynomial fit of the impurity lines called "internal standard" [10,11] and for using fitting coefficients to calculate wavelength of all lines. The input of the program and comments is given in the Table 2.1 and the internal standards fittings and the sample of the output is shown in the Table 2.2. The accuracy of the wavelength measurement of bromine lines in the entire region 300 Å-2080 Å for the sharp lines is ±0.005 Å.

Table: 2.1 Input file for the calibration of wavelengths

Br 05 (second track) from 410 Å to 605 Å

```
  3
  0.0500
194.0328     599.598
192.7510     597.818
181.5058     582.246
171.2062     567.977
165.1074     559.526
156.7074     547.879
140.7624     525.795
128.0438     508.182
109.2184     482.121
 99.2889     468.375
 57.7294     410.860
 -1.0         -1.0
  0            0
  0
197.6096     5
196.9638    85
195.7992    35
195.2332   100
```

Where,

1. The first line is the comment line.
2. The second line gives the degree of freedom for the polynomial.
3. The third line gives the wavelength tolerance.

   When the largest deviation is less than or equal to a given 'tolerance' the least square fit is successful. Otherwise it is assumed that there is something wrong with (at least) one of the calibration lines. Mosfit then rejects the line with the largest deviation and performs a new least-square fit without that line. This procedure is repeated until all calibration lines that were used are within the tolerance.
4. The following lines contain position of the calibration line and the standard wavelength.
5. The line with -1,-1 to indicate the end of the standard inputs.
6. A line with two numbers, which are used to select the type of output. The first number is the maximal order of the wavelength in the output. When this is zero or negative, Mosfit runs in manual mode and also asks for this number before creating the output file; when it is positive, Mosfit runs automatically.

   The second number in the number of characters per spectral line in the output; when this is zero, Mosfit determines the number of characters from the input file and use that. If a positive value is given, only the first so many characters are given on the list.

Table 2.2 Output file of the calibrated wavelengths

position	int	standard wavelength	fitted wavelength	difference	comment
57.7294	5	410.8600	410.8609	0.0009	
99.2889	75	468.3750	468.3722	-0.0028	
109.2184	5	482.1210	482.1184	-0.0026	
128.0438	30	508.1820	508.1850	0.0030	
140.7624	25	525.7950	525.7993	0.0043	
156.7074	17	547.8790	547.8854	0.0064	
165.1074	40	559.5260	559.5220	-0.0040	
171.2062	77	567.9770	567.9712	-0.0058	
181.5058	75	582.2460	582.2412	-0.0048	
192.7510	10	597.8180	597.8226	0.0046	
194.0328	20	599.5980	599.5988	0.0008	

Standard deviation = 0.00505

Polynomial of degree 3

0	331.0475972415
1	1.3816794592
2	0.0000160958
3	-0.0000000200

second order				first order	
λ(Å)	ν(cm^{-1})	position(mm)	int	λ(Å)	ν(cm^{-1})
302.2775	330821.80	197.6096	5	604.5551	165410.90
302.2335	330870.03	197.5460	6	604.4670	165435.01
301.8301	331312.22	196.9638	85	603.6602	165656.11
301.6770	331480.38	196.7428	85	603.3540	165740.19
301.0232	332200.29	195.7992	35	602.0464	166100.15
300.6311	332633.62	195.2332	100	601.2621	166316.81

Where,

First portion shows the fitted output with respect to given standards, the last column shows the deviation from the given standard λ. The standard deviation of the entire fit is 0.00505 Å.

The second portion shows the output of the calibrated wavelength and its different orders, in fact any desired order of the wavelengths can be obtained.

2.33 Ionization stages and their separation

For atoms, the proportion of the spectrum that falls below 2000Å increases rapidly with increasing stage of ionization, the wavelengths of the corresponding lines of the isoelectronic ions being for the main part inversely proportional to the effective charge. Spectral lines belonging to many ionization stages overlap in the far ultraviolet region, as a consequence.

The degree of ionization, responsible for the production of the spark spectrum, depends on the spark gap, vacuum in the source, and the LCR characteristics of the discharge circuit. We can increase the ionization involved by decreasing the spark gap, the vacuum or the capacitance and by reducing the inductance. High vacuum (10^{-6} torr) gives stability to the source in addition to avoid air absorption, of the spectrum.

The most important part of the analysis is ionization separation. After the preparation of the line list, ionization separation is done quite satisfactorily using the intensity variation and pole effect of individual spectral lines. The lines of different ionizations are discriminated by the gradual introduction of the inductance coil in the discharge circuit. We made a careful study of the intensity variation of the already known spectral lines of bromine on different tracks of the various plates and found some regular variations. We found good excitation of Br III, Br IV, Br V and Br VI lines on 6 kV track. However, on other tracks with different inductances, they behave differently. The intensity of Br IV lines falls gradually with increasing inductance while Br III lines remain nearly constant with increasing inductance. On the other hand the intensity of Br V lines fall more rapidly than Br IV lines with increasing inductance. The intensity of Br VI lines fall sharply on the lower voltages tracks and become short (polar). The Br VII lines are polar (short length) on the first track and disappear completely on inductance coil tracks. The weaker lines of Br VI also appear shorter on the first track (6 kV) but longer than Br VII lines. These variations provided us a very reliable ionization separation. In the lower wavelength region, on the grazing incidence exposure, Br IV and Br V lines were very well developed whereas Br VI and higher ions were either absent or very weak. These variations provided us some criteria of ionization discrimination in that region.

2.34 Level optimization

A least-square fitting computer program "KLAS" based on matrix inversion method was used to optimize the energy level values from the observed transitions. This program was developed by G. J. Van Het Hof of Amsterdam [13]. The levels uncertainty for majority of the levels was obtained by KLAS output. This program does not provide uncertainties in the level values when involving levels are more than ninety, then another program LOPT[14] developed by A. Kramida was used for this purpose.

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CHAPTER 3

The spectrum of doubly ionized bromine: Br III

The spectrum of doubly ionized bromine (Br III) has neutral Arsenic- like (As I) structure with $4s^24p^3$ as the ground state configuration. The excited configurations are $4s4p^4$, $4s^24p^2nd$ ($n \geq 4$) and $4s^24p^2ns$ ($n \geq 5$) and further excitations lead to odd parity configurations $4s^24p^2$ (5p+6p+4f+5f) + $4s4p^3$ (4d+5s). The earlier analyses of Br III were revised by Rao and Krishnamurty [1]. They studied ground configuration $4s^24p^3$ and the excited configurations $4s^24p^2$(5s+6s+4d+5d) and $4s^24p^25p$ and reported all five levels of the ground configuration, twenty-six levels from even parity as well as eighteen levels of $4p^25p$ configuration. Their work has already been compiled in the NIST atomic spectra database [2]. The analysis was further revised and extended by Bhupala Rao [3].

Persson and Patterson [4] pointed out the discrepancy in the reported ground levels of Br III [2]; consequently, Joshi et al [5] investigated $4s^24p^3 - 4s4p^4$ transition array of Br III. They could confirm only one ground level $4p^3\ ^2D_{5/2}$ apart from $^4S_{3/2}$ which is the ground most and revised all other ground levels. They also reported 8 levels of $4s4p^4$ configuration but did not study any level of $4p^2nd$ or $4p^2ns$ configurations. Most recently, Jabeen and Tauheed [6] re-investigated the spectrum of Br III in detail covering the $4s^24p^3$–[$4s4p^4$ + $4s^24p^2$ (4d + 5d + 6d + 5s + 6s + 7s)] transition array and have established 106 energy levels. They confirmed all the ground levels of Joshi et al [5] but only 6 levels of $4s4p^4$ configuration, two of them being revised. Out of 31 levels in NIST ASD compilation from this array, only 6 levels could be confirmed with significant improved accuracy and 6 others with changed designations. Jabeen and Tauheed [6] did not establish J=9/2 levels of $4p^2nd$ configurations as they do not combine with the ground levels. Their investigation includes two hundred and eighty-one classified lines in the wavelength range 409 - 1326Å. They also reported the ionization potential at 281247±100 cm^{-1} (34.8702±0.0124 eV).

The present investigation was undertaken due to several reasons. Firstly, due to the availability of the data in the higher wavelength region above 2000 Å which lead us to extend the study of excited configurations $4p^2(5p+4f)$, secondly, the reported levels in the literature have been revised extensively in recent study [6]; therefore, $4p^25p$ levels which were based on the earlier reported levels [2,3], needed confirmation. Thirdly, the other configuration $4p^24f$ has never been studied before and finally, the unknown J=9/2 levels of $4p^2nd$ configurations. These facts prompted us to undertake the present investigation.

3.1 The energy level structure:

The electronic distribution for ground configuration of doubly ionized Bromine (Br III) $1s^22s^22p^63s^23p^63d^{10}4s^24p^3$ gives rise to energy levels $^4S_{3/2}$, $^2D_{3/2,5/2}$ and $^2P_{1/2,3/2}$ in order of increasing energy.

The excited configurations of our interest along with the resulting levels are given as follows:

$4s4p^4$:		$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
		$^2D_{3/2,5/2}$
		$^2S_{1/2}$
$4s^24p^2ns(n\geq5)$:	(^3P)	$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1D)	$^2D_{3/2,5/2}$
	(^1S)	$^2S_{1/2}$
$4s^24p^25p$:	(^3P)	$^4D_{1/2,3/2,5/2,7/2}$
		$^4P_{1/2,3/2,5/2}$
		$^4S_{3/2}$
		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
		$^2S_{1/2}$
	(^1D)	$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$

		$^2P_{1/2,3/2}$
	(^1S)	$^2P_{1/2,3/2}$
$4s^24p^2nd(n\geq4)$:	(^3P)	$^4F_{3/2,5/2,7/2,9/2}$
		$^4D_{1/2,3/2,5/2,7/2}$
		$^4P_{1/2,3/2,5/2}$
		$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1D)	$^2G_{7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
		$^2S_{1/2}$
	(^1S)	$^2D_{3/2,5/2}$
$4s^24p^2nf(n\geq4)$:	(^3P)	$^4G_{5/2,7/2,9/2,11/2}$
		$^4F_{3/2,5/2,7/2,9/2}$
		$^4D_{1/2,3/2,5/2,7/2}$
		$^2G_{7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$
	(^1D)	$^2H_{9/2,11/2}$
		$^2G_{7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1S)	$^2F_{5/2,7/2}$

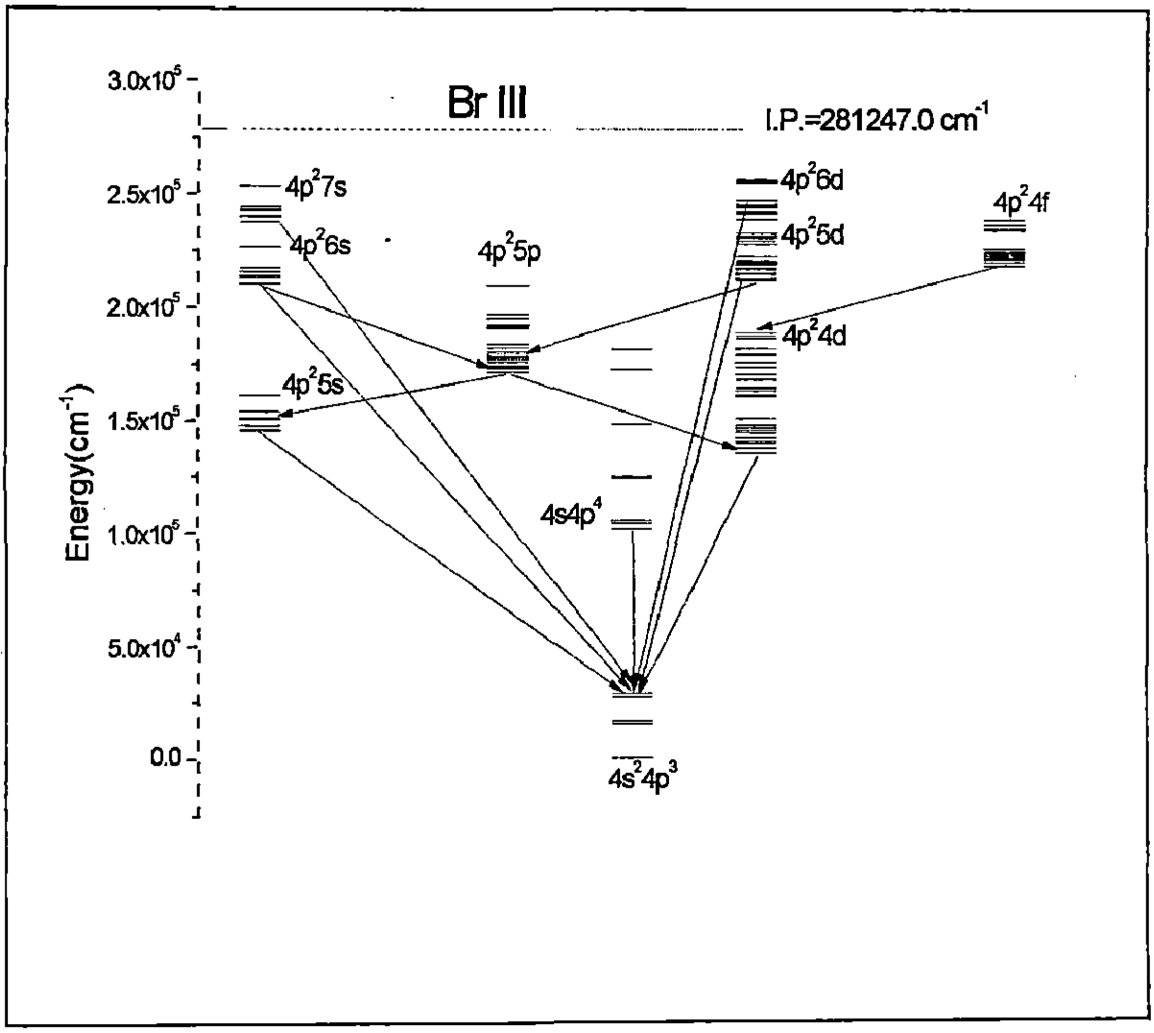

Fig. 3.1: Energy level diagram of doubly ionized bromine: Br III. The configurations shown in black colour are analyzed in earlier work [6] and that shown in red colour are studied in the present work. The ionization potential was also determined in the earlier work [6].

3.2 Ab initio calculations:

The theoretical predictions for this spectrum were obtained by using Cowan's Code [7] in HFR mode. The prominent interacting configurations included for odd parity system were $4s^24p^3$ + $4s^24p^2$ (5p+6p+4f+5f) + $4s4p^3$ (4d+5s) and that for even parity matrix $4s4p^4$ + $4s^24p^2$ (4d + 5d + 6d + 5s + 6s + 7s) + $4s4p^3$ (5p + 4f) + $4p^4$ (4d + 5s) + $4s4p^2$ ($4d^2$ + $5s^2$) + $4s^24p5s5p$ + $4s4p^24f^2$ for a reliable prediction. The *ab initio* values used for different energy parameters were as E_{av} and ζ at 100%, F^k at 85%, G^k and R^k at 75% and 80% of HFR values respectively. This set of scaling gives quite reliable predictions of the energy eigenvalues, transition probabilities and wavelengths of the transitions involved. Further, this scaling was refined by comparing the parameters with its isoelectronic ions Kr^{3+} [8, 9].

3.3 Analysis and discussions:

3.31 New analysis:

With the availability of extended data in higher wavelength region, it became possible to study the new configurations $4p^2 4f$ and $4p^2 5p$. As mentioned above, the $4p^2 5p$ configuration was reported by Rao and Krishnamurty [1] followed by Bhupala Rao [3]. However, their analysis was without any theoretical support. Since large number of even parity levels of Rao and Krishnamurty [1] and Bhupala Rao [3] were revised by Jabeen and Tauheed [6], the levels of $4p^2 5p$ configuration certainly require further investigation. Secondly, the $4p^2 4f$ configuration completely unknown, expected to give strong transitions to $4p^2 4d$ levels and lie mainly in our region of investigation, was the main motivation of the present analysis. Mostly the same plates are used for this analysis as were used in Ref. [6] except an extended line list above 2000 Å by Budhiraja [10] which became available to us only recently and also lines used in ref [1,3]. We started the analysis freshly from the beginning. All five levels of the ground configuration $4s^2 4p^3$ and one hundred-one levels of the excited configurations $4s4p^4 + 4s^2 4p^2$ (4d + 5d + 6d + 5s + 6s + 7s) reported in ref [6] were being confirmed in the present work. We have extended the existing analysis of Br III to further excitations leading to odd configurations $4p^2 5p$ and $4p^2 4f$.

3.32 The $4s^2 4p^2 5p$ configuration:

This configuration is connected with $4s^2 4p^2 nd$ ($n \geq 4$) and $4s^2 4p^2 ns$ ($n \geq 5$) configurations. The transition array [$4s^2 4p^2 4d + 4s^2 4p^2 5s - 4s^2 4p^2 5p$] was predicted quite strong by Cowan's code [7] but almost all these transitions were lying above 2000Å wavelength region. Due to strong mixing of the configurations $4s4p^4$, $4p^2 4d$ and $4p^2 5s$ with each other, moderately strong transitions from $4s4p^4$ to $4p^2 5p$ were also observed. These transitions lying below 2000Å were found on our plates and we were successful to establish all the 21 levels of this configuration. However, the main transitions from $4s^2 4p^2$ (4d+5d+5s+6s) lying above 2000Å were verified from the available list [10] covering the wavelength up to 2400Å. Above this wavelength, we used lines from the published lists of Rao and Krishnamurthy [1] as well as from

Bhupala Rao [3]. In the present work, we could confirm only 4 earlier reported levels and changed the designations of six other levels. Eleven new levels of $4p^25p$ configuration have been established satisfactorily. The leading LS purity of all the levels is greater than 50% except two levels $^4P_{3/2}$ at 176661.7 cm^{-1} which is 44% and the other one (^1D) $^2D_{5/2}$ at 192112.5 is 49%. However, for assigning LS designation they are still quite unambiguous. We should also point out that since the uncertainties above 2000 Å is expected to be higher than our estimated uncertainty; therefore, levels of the $4p^25p$ configuration were optimized separately. It appears from the optimized levels that wavelength error above 2000 Å could be as high as ± 0.08 Å. However, they were helpful in confirming the levels. All the levels agree well with the calculated values and fitting nicely in the least squares fitted parametric calculations.

With successful establishment of the $4p^25p$ (^3P) $^4D_{7/2}$ and (^1D) $^2F_{7/2}$ levels, it became possible to locate the four unknown J=9/2 levels of even parity configurations, namely $4p^2$ (4d+5d) (^3P) $^4F_{9/2}$ and (^1D) $^2G_{9/2}$. These levels were predicted very precisely by Jabeen and Tauheed [6] in their least squares fitted parametric calculations. We found strong respective transitions from the list of lines in ref [1] which were not being used in the present analysis. The two $4p^24d$ levels were found at 144157.5 cm^{-1} [(^3P) $^4F_{9/2}$], 161025.0 cm^{-1} [(^1D) $^2G_{9/2}$] and the other two of $4p^25d$ configuration at 216525.5 cm^{-1} and 228384.8 cm^{-1} respectively. These levels were found very close to the predicted parametric calculations.

It should be pointed out here that during the earlier investigation of Br III by Jabeen and Tauheed [6], 16 lines listed in the Kelly's compilation [11] were confirmed as transitions from ground levels however, five lines (1077.3Å, 1173.6 Å, 1228.9Å, 1377.2 Å and 1830.6 Å) which were the transitions between $4p^24d$- $4p^25p$, were not confirmed. In our investigation, we could confirm only one line at 1830.596Å; the other four lines were not seen on our list.

3.33 The $4s^24p^24f$ configuration:

The *ab initio* calculations were obtained with the inclusion of the interacting configurations as mentioned-above. Almost all the transitions between $4p^24d$ and $4p^24f$ lie on our plates and they were predicted to be quite strong. It was not very difficult to locate the first two levels $4p^24f\,(^3P)\,^2D_{3/2}$ and $4p^24f\,(^3P)\,^4G_{5/2}$ at 220898.9 and 217891.8 cm^{-1} respectively based on the identification of 9 and 6 transitions respectively. This established the initial shift from the calculated values. A further scaling of the E_{av} ($4p^24f$) gave very precise prediction of the remaining $4p^24f$ levels. This configuration also gave moderate transitions with $4s4p^4$ due to strong mixing with $4s^24p^24d$ as mentioned above. As a result, we were successful to find out 28 of the 30 possible energy levels of this configuration satisfactorily. However, their LS designations were not very unambiguous. About 73% of the levels have LS purities greater than 50% and are quite unambiguous. Among the remaining levels, the leading component can be assigned to level designation without much problem except a J=3/2 level at 220898.9 cm^{-1} has been assigned as third component $(^3P)\,^2D_{3/2}$ and another level a J=7/2 at 217983.0 cm^{-1} has been named as its second leading component $(^3P)^4G_{7/2}$. It was noticed from least squares fitted parametric calculations that $4p^24f$ configuration is interacting with $4s4p^34d$, therefore it was necessary to incorporate in the least squares fit. The fitted energy parameters were found to be in close agreement with Kr IV [8] which is isoelectronic with Br III.

3.4 Results:

The observed levels were optimized using LOPT [12] code of Dr. A. E. Kramida of NIST [USA]. A total of 504 spectral lines have been classified, out of which 209 are newly classified and they are given in Tables 3.1A and 3.1B along with the transition probabilities (gA) and weighted oscillator strength (log gf) as obtained with final least squares fitted energy parameters. 159 levels of Br III have now been established, 43 being new. For completeness; the comprehensive list of optimized Br III levels of both parities are given in Table 3.2 along with their uncertainties and the number of connecting lines. The least squares fitted (LSF) energy levels of odd and even parity configurations along with their LS percentage mixing are assembled in Table 3.3 and the corresponding energy parameters are given in Tables 3.4 and 3.5 respectively. The agreement with theoretical calculations was good. The standard deviations of least squares fit for odd and even parity configurations were 253 cm^{-1} and 213 cm^{-1} respectively.

A Grotorian energy level diagram of Br III has been shown in Fig. 3.1.

3.5 Ionization potential:

Three series members are required to calculate a reliable ionization potential of the ions. In the earlier work, Jabeen and Tauheed [6] studied $4p^2nd$ (n=4-6) and $4p^2ns$ (n=5-7) series; though $4p^26d$ and $4p^27s$ configurations only partially. They found a few levels of these configurations satisfactorily which were helpful in determining the ionization potential of Br III. Particularly, the $4p^2ns$ (^3P) $^4P_{1/2,3/2,5/2}$ levels show better LS purities than others. They, therefore, used $4p^2ns$ (^3P) ^4P series for final calculations of the series limit using Ritz formula [13] and found very consistent values from all three members. They adapted the average value of the series limit at 281247±100 cm^{-1} (34.8702±0.0124 eV) converging at $4p^2$ $^3P_0$ (Br IV).

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Table 3.1A: Classified lines of Br III in the [$4s^2p^3$ – ($4s4p^4$+$4p^2nd$ + $4p^2ns$)] and [($4s4p^4$+$4p^2nd$) – $4p^24f$] transition arrays.

I_{obs}[a]	λ_{obs}(Å)	σ_{obs}(cm^{-1})	λ_{Ritz}(Å)	λ_{obs}- λ_{Ritz} (Å)[b]	Lower level		Upper level	Log gf	gA(s^{-1})[c]
40	409.099[d]	244440	409.099	0	$4s^24p^3$	$^4S_{3/2}$	$4p^26d\ (^3P)\ ^4P_{1/2}$	-1.080	3.311E+09
40	409.262[d]	244342	409.262	0	$4s^24p^3$	$^4S_{3/2}$	$4p^26d\ (^3P)\ ^4P_{3/2}$	-0.934	4.629E+09
40	409.489[d]	244207	409.492	-0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^26d\ (^3P)\ ^4D_{5/2}$	-1.113	3.060E+09
25	411.474[d]	243029	411.475	-0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^27s\ (^3P)\ ^4P_{5/2}$	-1.416	1.510E+09
10	413.306[d]	241951	413.301	0.005	$4s^24p^3$	$^4S_{3/2}$	$4p^26d\ (^3P)\ ^4D_{3/2}$	-1.721	7.419E+08
50	414.577[d]	241210	414.583	-0.006	$4s^24p^3$	$^4S_{3/2}$	$4p^26d\ (^3P)\ ^2P_{3/2}$	-1.721	7.419E+08
40	414.879[d]	241034	414.878	0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^26d\ (^3P)\ ^4P_{5/2}$	-0.856	5.404E+09
10	415.581[d]	240627	415.582	-0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^26d\ (^1D)\ ^2D_{3/2}$	-0.930	4.534E+09
30	416.467[d]	240115	416.469	-0.002	$4s^24p^3$	$^4S_{3/2}$	$4p^27s\ (^3P)\ ^4P_{3/2}$	-1.462	1.328E+09
5	417.343[d]	239611	417.341	0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^1D)\ ^2D_{5/2}$	-1.305	1.896E+09
5	417.418[d]	239568	417.418	0	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^1D)\ ^2D_{3/2}$	-1.594	9.739E+08
40	418.195[d]	239123	418.195	0	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^1D)\ ^2G_{7/2}$	-0.751	6.776E+09
40	418.708[d]	238830	418.71	-0.002	$4s^24p^3$	$^4S_{3/2}$	$4p^26d\ (^3P)\ ^4F_{5/2}$	-0.856	5.404E+09
30	419.001[d]	238663	419.001	0	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^1D)\ ^2F_{7/2}$	-0.778	6.336E+09
40	419.280[d]	238504	419.280	0	$4s^24p^3$	$^2D_{3/2}$	$4p^27s\ (^1D)\ ^2D_{3/2}$	-1.345	1.716E+09
5	419.416[d]	238427	419.419	-0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^26d\ (^3P)\ ^4F_{3/2}$	-2.134	2.783E+08
30	420.858[d]	237610	420.861	-0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^27s\ (^3P)\ ^4P_{1/2}$	-1.859	5.211E+08
50	421.212[d]	237410	421.212	0	$4s^24p^3$	$^2D_{5/2}$	$4p^27s\ (^1D)\ ^2D_{5/2}$	-1.089	3.060E+09
10	429.904[d]	232610	429.903	0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^1D)\ ^2S_{1/2}$	-2.726	6.790E+07
20	431.794[d]	231592	431.793	0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^26d\ (^3P)\ ^2D_{5/2}$	-1.360	1.562E+09
20	431.891[d]	231540	431.888	0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^1D)\ ^2P_{3/2}$	-2.248	2.012E+08
20	433.774[d]	230535	433.775	-0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^3P)\ ^2D_{5/2}$	-1.178	2.354E+09
70	436.614[d]	229035	436.614	0	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^3P)\ ^2F_{7/2}$	-0.166	2.391E+10
10	436.767[d]	228955	436.765	0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^26d\ (^3P)\ ^4D_{5/2}$	-2.048	3.128E+08
18	437.390[d]	228629	437.382	0.008	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\ (^1S)\ ^2D_{5/2}$	-1.488	1.130E+09
10	438.827[d]	227880	438.828	-0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^27s\ (^3P)\ ^2P_{3/2}$	-1.111	2.668E+09
5	439.022[d]	227779	439.022	0	$4s^24p^3$	$^2D_{3/2}$	$4p^27s\ (^3P)\ ^4P_{5/2}$	-2.415	1.331E+08
40	439.242[d]	227665	439.242	0	$4s^24p^3$	$^2P_{3/2}$	$4p^26d\ (^1D)\ ^2P_{3/2}$	-0.925	4.111E+09
6	439.589[d]	227485	439.589	0	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^3P)\ ^4D_{7/2}$	-2.371	1.468E+08
50	440.047[d]	227248	440.051	-0.004	$4s^24p^3$	$^2P_{3/2}$	$4p^26d\ (^1D)\ ^2D_{5/2}$	-0.563	9.436E+09
60	440.665[d]	226930	440.665	0	$4s^24p^3$	$^2D_{3/2}$	$4p^26d\ (^3P)\ ^2F_{5/2}$	-0.332	1.603E+10
30	441.102[d]	226705	441.101	0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^26d\ (^3P)\ ^4D_{3/2}$	-1.468	1.165E+09
5	441.387[d]	226559	441.395	-0.008	$4s^24p^3$	$^2P_{1/2}$	$4p^27s\ (^1D)\ ^2D_{3/2}$	-2.165	2.339E+08
40	444.051[d]	225199	444.053	-0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^27s\ (^3P)\ ^2P_{1/2}$	-1.302	1.687E+09
20	444.295[d]	225076	444.285	0.01	$4s^24p^3$	$^2P_{3/2}$	$4p^27s\ (^1D)\ ^2D_{3/2}$	-1.480	1.118E+09
8	444.355[d]	225045	444.356	-0.001	$4s^24p^3$	$^2P_{3/2}$	$4p^27s\ (^1D)\ ^2D_{5/2}$	-1.923	4.033E+08
15	444.639[d]	224902	444.644	-0.005	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^3P)\ ^2P_{3/2}$	-2.340	1.549E+08
30	445.054[d]	224692	445.054	0	$4s^24p^3$	$^2D_{5/2}$	$4p^26d\ (^3P)\ ^4F_{7/2}$	-1.226	1.999E+09
10	446.814[d]	223807	446.813	0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^27s\ (^3P)\ ^4P_{3/2}$	-1.929	3.937E+08
50	447.267[d]	223580	447.267	0	$4s^24p^3$	$^2D_{3/2}$	$4p^26d\ (^3P)\ ^4F_{5/2}$	-1.109	2.595E+09
5	448.070[d]	223179	448.076	-0.006	$4s^24p^3$	$^2D_{3/2}$	$4p^26d\ (^3P)\ ^4F_{3/2}$	-2.098	2.649E+08

30	449.726[d]	222358	449.723	0.003	$4s^24p^3$	$^2D_{3/2}$	$4p^27s\ (^3P)$	$^4P_{1/2}$	-1.829	4.886E+08
70	454.740[d]	219906	454.745	-0.005	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\ (^1S)$	$^2D_{3/2}$	-0.247	1.831E+10
30	454.942[d]	219808	454.942	0	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^2P_{1/2}$	-2.540	9.302E+07
80	456.221[d]	219192	456.221	0	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^4P_{1/2}$	-0.481	1.057E+10
80	456.805[d]	218912	456.805	0	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^4P_{3/2}$	-0.269	1.719E+10
80	457.821[d]	218426	457.820	0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^4D_{5/2}$	-0.363	1.377E+10
80	457.821[d]	218426	457.813	0.008	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\ (^1S)$	$^2D_{3/2}$	-0.849	4.514E+09
30	457.977[d]	218352	457.973	0.004	$4s^24p^3$	$^2P_{1/2}$	$4p^26s\ (^1S)$	$^2S_{1/2}$	-1.612	7.756E+08
80	458.363[d]	218168	458.361	0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^26d\ (^3P)$	$^2D_{5/2}$	-0.135	2.332E+10
50	460.065[d]	217361	460.062	0.003	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\ (^1D)$	$^2S_{1/2}$	-1.781	5.225E+08
40	460.855[d]	216988	460.855	0	$4s^24p^3$	$^2P_{1/2}$	$4p^27s\ (^3P)$	$^2P_{3/2}$	-1.554	8.712E+08
80	461.081[d]	216882	461.085	-0.004	$4s^24p^3$	$^2P_{3/2}$	$4p^26s\ (^1S)$	$^2S_{1/2}$	-1.548	8.864E+08
80	461.089[d]	216878	461.084	0.005	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^2F_{5/2}$	-1.082	2.604E+09
30	462.137[d]	216386	462.140	-0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^2P_{3/2}$	-2.198	1.981E+08
20	462.383[d]	216271	462.390	-0.007	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\ (^1S)$	$^2D_{5/2}$	-1.988	3.198E+08
80	463.146[d]	215915	463.145	0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^26s\ (^3P)$	$^4P_{5/2}$	-1.171	2.097E+09
70	463.724[d]	215646	463.724	0	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\ (^1D)$	$^2D_{5/2}$	-0.950	3.483E+09
40	464.007[d]	215514	464.007	0	$4s^24p^3$	$^2P_{3/2}$	$4p^27s\ (^3P)$	$^2P_{3/2}$	-1.225	1.832E+09
50	464.561[d]	215257	464.563	-0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\ (^1D)$	$^2P_{1/2}$	-1.132	2.274E+09
80	464.927[d]	215088	464.930	-0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^4P_{5/2}$	-0.275	1.637E+10
60	465.255[d]	214936	465.255	0	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\ (^1D)$	$^2D_{3/2}$	-0.423	1.164E+10
70	465.400[d]	214869	465.400	0	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^4D_{3/2}$	-0.938	3.548E+09
40	465.647[d]	214755	465.645	0.002	$4s^24p^3$	$^2P_{1/2}$	$4p^26d\ (^3P)$	$^4D_{3/2}$	-1.392	1.245E+09
70	466.011[d]	214587	466.010	0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\ (^1D)$	$^2D_{5/2}$	-0.876	4.092E+09
80	467.464[d]	213920	467.464	0	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\ (^1D)$	$^2F_{5/2}$	-0.203	1.918E+10
30	467.554[d]	213879	467.557	-0.003	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\ (^1D)$	$^2D_{3/2}$	-1.024	2.887E+09
10	468.855[d]	213286	468.863	-0.008	$4s^24p^3$	$^2P_{3/2}$	$4p^26d\ (^3P)$	$^4D_{3/2}$	-1.979	3.180E+08
20	468.938[d]	213248	468.936	0.002	$4s^24p^3$	$^2P_{1/2}$	$4p^27s\ (^3P)$	$^2P_{1/2}$	-1.838	4.401E+08
80	469.471[d]	213006	469.467	0.004	$4s^24p^3$	$^4S_{3/2}$	$4p^26s\ (^3P)$	$^4P_{3/2}$	-0.925	3.598E+09
80	469.789[d]	212862	469.788	0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\ (^1D)$	$^2F_{5/2}$	-0.339	1.388E+10
80	469.867[d]	212826	469.867	0	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\ (^1D)$	$^2F_{7/2}$	0.061	3.477E+10
6	470.521[d]	212530	470.514	0.007	$4s^24p^3$	$^2P_{3/2}$	$4p^26d\ (^3P)$	$^2P_{3/2}$	-1.979	3.180E+08
70	470.723[d]	212439	470.724	-0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^4F_{5/2}$	-0.999	3.017E+09
5	470.890[d]	212364	470.893	-0.003	$4s^24p^3$	$^2P_{3/2}$	$4p^26d\ (^3P)$	$^4P_{5/2}$	-1.843	4.326E+08
40	472.371[d]	211698	472.373	-0.002	$4s^24p^3$	$^4S_{3/2}$	$4p^25d\ (^3P)$	$^4F_{3/2}$	-1.892	3.830E+08
80	472.684[d]	211558	472.682	0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^26s\ (^1D)$	$^2D_{3/2}$	-0.812	4.599E+09
80	472.684[d]	211558	472.684	0	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\ (^1D)$	$^2G_{7/2}$	-0.476	9.967E+09
50	472.972[d]	211429	472.973	-0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^26s\ (^1D)$	$^2D_{5/2}$	-1.402	1.179E+09
5	473.433[d]	211223	473.425	0.008	$4s^24p^3$	$^2P_{1/2}$	$4p^26d\ (^3P)$	$^4F_{3/2}$	-1.789	4.840E+08
70	474.854[d]	210591	474.853	0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^26s\ (^3P)$	$^4P_{1/2}$	-1.310	1.447E+09
20	475.058[d]	210501	475.057	0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^26s\ (^1D)$	$^2D_{3/2}$	-2.649	6.628E+07
80	475.355[d]	210369	475.351	0.004	$4s^24p^3$	$^2D_{5/2}$	$4p^26s\ (^1D)$	$^2D_{5/2}$	-0.574	7.864E+09
70	483.631[d]	206769	483.632	-0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\ (^3P)$	$^2D_{5/2}$	-0.382	1.186E+10
60	486.119[d]	205711	486.119	.0	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\ (^3P)$	$^2D_{5/2}$	-0.548	8.005E+09
60	486.221[d]	205668	486.222	-0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\ (^3P)$	$^2D_{3/2}$	-1.322	1.349E+09

40	486.825[d]	205413	486.826	-0.001	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^1D)$	$^2S_{1/2}$	-1.226	1.667E+09
30	488.857[d]	204559	488.855	0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^2P_{1/2}$	-2.014	2.703E+08
30	489.372[d]	204344	489.373	-0.001	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^1D)$	$^2P_{3/2}$	-1.194	1.775E+09
80	490.122[d]	204031	490.122	0	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^2F_{7/2}$	0.003	2.801E+10
80	490.342[d]	203939	490.344	-0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^1D)$	$^2S_{1/2}$	-0.600	6.984E+09
10	491.007[d]	203663	491.007	0	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^4P_{3/2}$	-2.124	2.076E+08
70	491.869[d]	203306	491.868	0.001	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^1D)$	$^2P_{1/2}$	-0.978	2.889E+09
30	492.184[d]	203176	492.180	0.004	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^4D_{5/2}$	-1.306	1.358E+09
80	492.647[d]	202985	492.645	0.002	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^1D)$	$^2D_{3/2}$	-0.772	4.642E+09
80	492.929[d]	202869	492.929	0	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^1D)$	$^2P_{3/2}$	-0.326	1.291E+10
30	493.571[d]	202605	493.571	0	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^4P_{3/2}$	-1.950	3.067E+08
80	494.397[d]	202267	494.398	-0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^26s\,(^3P)$	$^2P_{3/2}$	-0.997	2.746E+09
80	494.506[d]	202222	494.506	0	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^1D)$	$^2D_{5/2}$	0.000	2.733E+10
50	494.753[d]	202121	494.757	-0.004	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^4D_{5/2}$	-1.268	1.469E+09
90	495.953[d]	201632	495.954	-0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^2F_{5/2}$	-0.245	1.545E+10
20	496.248[d]	201512	496.248	0	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^1D)$	$^2D_{3/2}$	-0.045	2.442E+08
70	496.998[d]	201208	496.998	0	$4s^24p^3$	$^2D_{5/2}$	$4p^26s\,(^3P)$	$^2P_{3/2}$	-1.393	1.091E+09
80	497.171[d]	201138	497.176	-0.005	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^2P_{3/2}$	-1.096	2.167E+09
30	497.872[d]	200855	497.872	0	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^4D_{7/2}$	-2.260	1.478E+08
40	498.567[d]	200575	498.570	-0.003	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^2F_{5/2}$	-1.622	6.419E+08
30	498.761[d]	200497	498.762	-0.001	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^1D)$	$^2F_{5/2}$	-1.965	2.917E+07
90	499.803[d]	200079	499.805	-0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^2P_{3/2}$	-0.684	5.530E+09
30	500.405[d]	199838	500.407	-0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^4P_{5/2}$	-1.969	2.858E+08
60	500.958[d]	199618	500.952	0.006	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^4D_{3/2}$	-1.993	2.702E+08
30	503.074[d]	198778	503.070	0.004	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^4P_{5/2}$	-1.987	2.715E+08
90	503.621[d]	198562	503.621	0	$4s^24p^3$	$^2D_{3/2}$	$4p^26s\,(^3P)$	$^2P_{1/2}$	-0.814	4.041E+09
90	503.621[d]	198562	503.621	0	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^4D_{3/2}$	-1.162	1.811E+09
60	504.704[d]	198136	504.706	-0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^26s\,(^1D)$	$^2D_{3/2}$	-0.949	2.945E+09
30	505.035[d]	198006	505.037	-0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^26s\,(^1D)$	$^2D_{5/2}$	-1.560	7.194E+08
50	505.175[d]	197951	505.175	0	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^4F_{7/2}$	-1.314	1.268E+09
65	507.128[d]	197189	507.125	0.003	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^4F_{5/2}$	-1.238	1.497E+09
50	508.389[d]	196700	508.387	0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^26s\,(^3P)$	$^4P_{3/2}$	-1.609	6.357E+08
10	509.041[d]	196448	509.040	0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^25d\,(^3P)$	$^4F_{3/2}$	-1.763	4.442E+08
5	509.858[d]	196133	509.860	-0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^4F_{5/2}$	-2.388	1.049E+08
10	511.797[d]	195390	511.796	0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^25d\,(^3P)$	$^4F_{3/2}$	-2.477	8.487E+07
60	511.925[d]	195341	511.921	0.004	$4s^24p^3$	$^2D_{3/2}$	$4p^26s\,(^3P)$	$^4P_{1/2}$	-1.550	7.161E+08
50	513.410[d]	194776	513.411	-0.001	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^3P)$	$^2D_{3/2}$	-0.264	1.384E+10
60	517.210[d]	193345	517.209	0.001	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^3P)$	$^2D_{5/2}$	-0.286	1.293E+10
70	517.327[d]	193301	517.325	0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^3P)$	$^2D_{3/2}$	-0.668	5.377E+09
70	519.182[d]	192611	519.184	-0.002	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^3P)$	$^2P_{1/2}$	-0.560	6.816E+09
40	523.188[d]	191136	523.188	0	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^3P)$	$^2P_{1/2}$	-0.921	2.922E+09
50	525.436[d]	190318	525.441	-0.005	$4s^24p^3$	$^2P_{1/2}$	$4p^26s\,(^3P)$	$^2P_{3/2}$	-0.654	5.357E+09
60	528.583[d]	189185	528.580	0.003	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^3P)$	$^2P_{3/2}$	-1.484	7.845E+08
60	529.546[d]	188841	529.542	0.004	$4s^24p^3$	$^2P_{3/2}$	$4p^26s\,(^3P)$	$^2P_{3/2}$	-0.521	7.155E+09
20	532.198[d]	187900	532.194	0.004	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^3P)$	$^4D_{1/2}$	-1.620	5.643E+08
5	532.734[d]	187711	532.730	0.004	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^3P)$	$^2P_{3/2}$	-2.635	5.453E+07

10	532.843[d]	187673	532.850	-0.007	$4s^24p^3$	$^2P_{1/2}$	$4p^25d\,(^3P)$	$^4D_{3/2}$	-1.814	3.602E+08
20	536.397[d]	186429	536.401	-0.004	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^3P)$	$^4D_{1/2}$	-1.945	2.631E+08
10	537.069[d]	186196	537.068	0.001	$4s^24p^3$	$^2P_{3/2}$	$4p^25d\,(^3P)$	$^4D_{3/2}$	-1.431	8.573E+08
20	538.181[d]	185811	538.188	-0.007	$4s^24p^3$	$^2P_{1/2}$	$4p^26s\,(^3P)$	$^4P_{3/2}$	-2.940	2.645E+07
5	542.493[d]	184334	542.491	0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^26s\,(^3P)$	$^4P_{3/2}$	-2.030	2.117E+08
57	545.274[d]	183394	545.278	-0.004	$4s^24p^3$	$^2P_{1/2}$	$4p^26s\,(^3P)$	$^4P_{1/2}$	-2.220	1.350E+08
80	559.751[d]	178651	559.748	0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^1D)$	$^2D_{5/2}$	-2.207	1.318E+08
5	561.324[d]	178150	561.319	0.005	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^1D)$	$^2D_{3/2}$	-3.406	8.314E+06
10	570.859[d]	175175	570.860	-0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^2F_{5/2}$	-3.151	1.444E+07
40	577.651[d]	173114.9	577.645	0.006	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^1D)$	$^2P_{1/2}$	-1.816	3.065E+08
65	580.963[d]	172128	580.963	0	$4s^24p^3$	$^4S_{3/2}$	$4s4p^4$	$^2P_{3/2}$	-1.071	1.678E+09
80	582.447[d]	171689.4	582.444	0.003	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^1S)$	$^2D_{3/2}$	-2.256	1.092E+08
50	586.054[d]	170632.7	586.056	-0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^1S)$	$^2D_{3/2}$	-2.204	1.215E+08
60	587.864[d]	170107.4	587.865	-0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^2D_{5/2}$	-1.495	6.175E+08
60	588.797[d]	169837.8	588.795	0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^1S)$	$^2D_{5/2}$	-2.074	1.620E+08
67	596.288[d]	167704.2	596.289	-0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^2D_{3/2}$	-1.668	4.023E+08
50	602.057[d]	166097.2	602.056	0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^1D)$	$^2P_{3/2}$	-2.072	1.565E+08
80	603.362[d]	165738	603.359	0.003	$4s^24p^3$	$^2D_{3/2}$	$4s4p^4$	$^2P_{1/2}$	-0.636	4.229E+09
70	605.910[d]	165041	605.915	-0.005	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^1D)$	$^2P_{3/2}$	-0.307	9.003E+09
100	608.499[d]	164339	608.499	0	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^4P_{1/2}$	0.409	4.623E+10
130	611.028[d]	163659	611.032	-0.004	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^4P_{3/2}$	0.692	8.784E+10
45	611.987[d]	163402.2	611.984	0.003	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^1D)$	$^2D_{5/2}$	-2.243	1.015E+08
110	613.861[d]	162903	613.8622	-0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^1D)$	$^2D_{3/2}$	0.541	6.152E+10
130	614.952[d]	162614	614.949	0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^4P_{5/2}$	0.655	7.963E+10
100	615.971[d]	162345	615.972	-0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^1D)$	$^2D_{5/2}$	0.614	7.199E+10
65	616.673[d]	162160.5	616.673	0	$4s^24p^3$	$^2D_{3/2}$	$4p^25s\,(^1S)$	$^2S_{1/2}$	-2.163	1.202E+08
75	617.880[d]	161843.7	617.875	0.005	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^1D)$	$^2D_{3/2}$	-0.351	7.779E+09
75	620.167[d]	161246.9	620.165	0.002	$4s^24p^3$	$^2P_{1/2}$	$4p^24d\,(^1D)$	$^2S_{1/2}$	-1.099	1.374E+09
100	620.350[d]	161199.3	620.350	-0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^25s\,(^1D)$	$^2D_{5/2}$	0.453	4.954E+10
77	620.467[d]	161168.9	620.474	-0.007	$4s^24p^3$	$^4S_{3/2}$	$4p^25s\,(^1D)$	$^2D_{3/2}$	-1.119	1.323E+09
130	625.289[d]	159926	625.291	-0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^2F_{5/2}$	0.761	9.807E+10
90	625.882[d]	159774.5	625.886	-0.004	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^1D)$	$^2S_{1/2}$	0.124	2.252E+10
90	626.018[d]	159739.8	626.015	0.003	$4s^24p^3$	$^2P_{1/2}$	$4p^24d\,(^1S)$	$^2D_{3/2}$	0.545	5.987E+10
150	628.556[d]	159094.8	628.555	0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^2F_{7/2}$	1.033	1.820E+11
100	629.452[d]	158868.3	629.455	-0.003	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^2F_{5/2}$	0.102	2.122E+10
85	631.840[d]	158267.9	631.845	-0.005	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^1S)$	$^2D_{3/2}$	-0.308	8.242E+09
80	633.442[d]	157867.7	633.441	0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^1D)$	$^2P_{1/2}$	0.271	3.119E+10
135	635.030[d]	157472.9	635.030	0	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^1S)$	$^2D_{5/2}$	0.821	1.095E+11
90	637.431[d]	156879.7	637.433	-0.002	$4s^24p^3$	$^2D_{3/2}$	$4s4p^4$	$^2P_{3/2}$	-0.079	1.371E+10
130	641.759[d]	155821.7	641.761	-0.002	$4s^24p^3$	$^2D_{5/2}$	$4s4p^4$	$^2P_{3/2}$	0.560	5.890E+10
120	645.755[d]	154857.5	645.752	0.003	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^2D_{5/2}$	0.358	3.651E+10
90	648.720[d]	154149.7	648.727	-0.007	$4s^24p^3$	$^2P_{1/2}$	$4p^24d\,(^1D)$	$^2P_{3/2}$	-0.009	1.559E+10
70	649.959[d]	153855.9	649.961	-0.002	$4s^24p^3$	$^4S_{3/2}$	$4p^25s\,(^3P)$	$^2P_{3/2}$	-1.673	3.351E+08
120	650.191[d]	153801	650.194	-0.003	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^2D_{5/2}$	0.360	3.623E+10
150	650.232[d]	153791.3	650.241	-0.009	$4s^24p^3$	$^2P_{1/2}$	$4s4p^4$	$^2P_{1/2}$	0.261	2.872E+10

100	654.994[d]	152673.2	654.990	0.004	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^1D)$	$^2P_{3/2}$	0.636	6.753E+10
100	655.931[d]	152455.1	655.930	0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^2D_{3/2}$	0.138	2.127E+10
110	656.537[d]	152314.3	656.533	0.004	$4s^24p^3$	$^2P_{3/2}$	$4s4p^4$	$^2P_{1/2}$	-0.034	1.431E+10
80	660.512[d]	151397.7	660.514	-0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^2D_{3/2}$	-1.195	9.752E+08
65	662.016[d]	151053.8	662.013	0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^25s\,(^3P)$	$^2P_{1/2}$	-2.029	1.423E+08
70	662.452[d]	150954.3	662.457	-0.005	$4s^24p^3$	$^2P_{1/2}$	$4p^24d\,(^1D)$	$^2D_{3/2}$	-0.719	2.904E+09
110	665.553[d]	150251	665.552	0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^25s\,(^3P)$	$^4P_{5/2}$	0.103	1.905E+10
80	665.733[d]	150210.4	665.732	0.001	$4s^24p^3$	$^2P_{1/2}$	$4p^25s\,(^1S)$	$^2S_{1/2}$	-0.060	1.308E+10
90	666.749[d]	149981.5	666.758	-0.009	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^1D)$	$^2D_{5/2}$	-0.028	1.402E+10
70	668.982[d]	149480.9	668.989	-0.007	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^1D)$	$^2D_{3/2}$	-0.379	6.221E+09
58	670.737[d]	149089.7	670.735	0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^4P_{1/2}$	-2.095	1.193E+08
80	672.327[d]	148737.1	672.329	-0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^25s\,(^1S)$	$^2S_{1/2}$	-0.175	9.823E+09
30	673.807[d]	148410.4	673.815	-0.008	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^4P_{3/2}$	-3.287	7.577E+06
90	676.403[d]	147840.9	676.395	0.008	$4s^24p^3$	$^4S_{3/2}$	$4s4p^4$	$^2S_{1/2}$	-2.855	2.041E+07
95	677.218[d]	147662.9	677.218	-0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^25s\,(^3P)$	$^4P_{3/2}$	-0.136	1.063E+10
90	677.739[d]	147549.4	677.739	-0.004	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^4D_{5/2}$	-1.076	1.217E+09
90	678.655[d]	147350.3	678.653	0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^4P_{3/2}$	-1.130	1.073E+09
75	682.581[d]	146502.8	682.585	-0.004	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^3P)$	$^2F_{5/2}$	-0.669	3.061E+09
85	683.158[d]	146379.0	683.156	0.002	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^4D_{3/2}$	-1.179	9.442E+08
95	683.489[d]	146308.1	683.488	0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^4P_{5/2}$	-0.811	2.202E+09
65	684.193[d]	146157.6	684.194	-0.001	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^4D_{1/2}$	-2.306	7.028E+07
90	685.156[d]	145952.2	685.156	-0.007	$4s^24p^3$	$^2D_{3/2}$	$4p^25s\,(^1D)$	$^2D_{5/2}$	-1.125	1.074E+09
70	685.314[d]	145919	685.315	-0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^25s\,(^1D)$	$^2D_{3/2}$	-0.440	5.191E+09
70	685.314[d]	145919.0	685.315	-0.001	$4s^24p^3$	$^2P_{1/2}$	$4p^24d\,(^1D)$	$^2P_{1/2}$	-1.396	5.739E+08
100	687.713[d]	145409.5	687.717	-0.004	$4s^24p^3$	$^4S_{3/2}$	$4p^25s\,(^3P)$	$^4P_{1/2}$	-0.434	5.183E+09
95	688.867[d]	145165.9	688.870	-0.003	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^1D)$	$^2F_{5/2}$	-1.510	4.342E+08
67	689.996[d]	144928.4	689.991	0.005	$4s^24p^3$	$^2P_{1/2}$	$4s4p^4$	$^2P_{3/2}$	-2.047	1.259E+08
100	690.170[d]	144891.8	690.169	0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^25s\,(^1D)$	$^2D_{5/2}$	-0.062	1.224E+10
35	690.325[d]	144859.3	690.320	0.005	$4s^24p^3$	$^2D_{5/2}$	$4p^25s\,(^1D)$	$^2D_{3/2}$	-2.370	6.013E+07
22	692.300[d]	144446	692.308	-0.008	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^1D)$	$^2P_{1/2}$	-1.360	5.799E+08
75	695.196[d]	143844.3	695.199	-0.003	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^1D)$	$^2G_{7/2}$	-0.971	1.480E+09
75	697.081[d]	143455.4	697.080	0.001	$4s^24p^3$	$^2P_{3/2}$	$4s4p^4$	$^2P_{3/2}$	-0.429	4.780E+09
110	707.038[d]	141435.1	707.040	-0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^3P)$	$^2D_{5/2}$	-0.324	6.334E+09
50	710.548[d]	140736.4	710.553	-0.005	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^4F_{5/2}$	-2.152	9.321E+07
95	711.709[d]	140506.9	711.716	-0.007	$4s^24p^3$	$^2P_{1/2}$	$4p^24d\,(^3P)$	$^2D_{3/2}$	-0.097	1.052E+10
50	715.394[d]	139783.1	715.399	-0.005	$4s^24p^3$	$^4S_{3/2}$	$4p^24d\,(^3P)$	$^4F_{3/2}$	-2.832	1.920E+07
90	719.254[d]	139032.9	719.261	-0.007	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^3P)$	$^2D_{3/2}$	-0.737	2.361E+09
45	721.472[d]	138605.5	721.466	0.006	$4s^24p^3$	$^2D_{3/2}$	$4p^25s\,(^3P)$	$^2P_{3/2}$	-2.818	1.944E+07
130	727.015[d]	137548.7	727.015	0	$4s^24p^3$	$^2D_{5/2}$	$4p^25s\,(^3P)$	$^2P_{3/2}$	0.093	1.561E+10
50	732.828[d]	136457.7	732.821	0.007	$4s^24p^3$	$^2P_{1/2}$	$4p^24d\,(^3P)$	$^4P_{3/2}$	-2.316	5.992E+07
100	736.348[d]	135805.4	736.348	0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^25s\,(^3P)$	$^2P_{1/2}$	-0.126	9.197E+09
6	737.104[d]	135666.1	737.102	0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^3P)$	$^4P_{1/2}$	-4.008	1.205E+06
67	740.722[d]	135003.4	740.728	-0.006	$4s^24p^3$	$^2D_{3/2}$	$4p^25s\,(^3P)$	$^4P_{5/2}$	-3.392	4.922E+06
75	740.820[d]	134985.6	740.823	-0.003	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^3P)$	$^4P_{3/2}$	-3.158	8.440E+06
75	745.494[d]	134139.2	745.494	0	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^1D)$	$^2F_{7/2}$	-1.489	3.889E+08

90	746.584[d]	133943.4	746.578	0.006	$4s^24p^3$	$^2D_{5/2}$	$4p^25s\,(^3P)$	$^4P_{5/2}$	-1.407	4.687E+08
90	746.584[d]	133943.4	746.587	-0.003	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^3P)$	$^4P_{5/2}$	-1.803	1.880E+08
50	751.496	133067.9	751.502	-0.006	$4s4p^4$	$^4P_{1/2}$	$4p^24f\,(^1D)$	$^2P_{3/2}$	-1.156	8.117E+08
70	754.003	132625.5	754.007	-0.004	$4s4p^4$	$^4P_{1/2}$	$4p^24f\,(^1D)$	$^2P_{1/2}$	-0.876	1.545E+09
75	754.179[d]	132594.5	754.184	-0.005	$4s^24p^3$	$^2D_{3/2}$	$4s4p^4$	$^2S_{1/2}$	-1.678	2.468E+08
90	754.565[d]	132526.7	754.566	-0.001	$4s^24p^3$	$^2P_{3/2}$	$4p^25s\,(^1D)$	$^2D_{5/2}$	-1.485	3.871E+08
70	755.216[d]	132412.4	755.211	0.005	$4s^24p^3$	$^2D_{3/2}$	$4p^25s\,(^3P)$	$^4P_{3/2}$	-1.979	1.227E+08
70	755.860[d]	132299.6	755.860	0	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^4D_{5/2}$	-1.757	2.039E+08
75	761.290[d]	131356	761.294	-0.004	$4s^24p^3$	$^2D_{5/2}$	$4p^25s\,(^3P)$	$^4P_{3/2}$	-1.455	4.027E+08
70	761.955[d]	131241.3	761.953	0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^4D_{5/2}$	-1.522	3.449E+08
65	762.594[d]	131131.4	762.598	-0.004	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^4D_{3/2}$	-2.283	5.970E+07
67	763.887[d]	130909.4	763.892	-0.005	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^4D_{1/2}$	-2.160	7.902E+07
75	768.285[d]	130160.0	768.286	-0.001	$4s^24p^3$	$^2D_{3/2}$	$4p^25s\,(^3P)$	$^4P_{1/2}$	-1.609	2.776E+08
100	768.800[d]	130072.8	768.801	-0.001	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^4D_{3/2}$	-2.325	5.331E+07
90	769.727[d]	129916.2	769.725	0.002	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^1D)$	$^2F_{5/2}$	-1.574	2.996E+08
45	770.079[d]	129856.8	770.082	-0.003	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^4D_{7/2}$	-2.699	2.239E+07
100	789.531[d]	126657.5	789.534	-0.003	$4s^24p^3$	$^2P_{1/2}$	$4p^25s\,(^3P)$	$^2P_{3/2}$	-1.009	1.048E+09
75	794.144[d]	125921.7	794.142	0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^4F_{7/2}$	-1.945	1.203E+08
75	796.897[d]	125486.7	796.897	0	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^4F_{5/2}$	-2.067	9.030E+07
100	798.827[d]	125183.6	798.830	-0.003	$4s^24p^3$	$^2P_{3/2}$	$4p^25s\,(^3P)$	$^2P_{3/2}$	-0.563	2.856E+09
50	801.686[d]	124737.1	801.687	-0.001	$4s^24p^3$	$^4S_{3/2}$	$4s4p^4$	$^2D_{5/2}$	-3.234	6.046E+06
85	803.002[d]	124532.7	802.998	0.004	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^4F_{3/2}$	-2.138	7.544E+07
63	803.675[d]	124428.4	803.673	0.002	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^4F_{5/2}$	-2.395	4.169E+07
85	807.385[d]	123856.6	807.390	-0.005	$4s^24p^3$	$^2P_{1/2}$	$4p^25s\,(^3P)$	$^2P_{1/2}$	-0.948	1.153E+09
67	817.120[d]	122381	817.114	0.006	$4s^24p^3$	$^2P_{3/2}$	$4p^25s\,(^3P)$	$^2P_{1/2}$	-2.263	5.445E+07
5	817.203	122368.6	817.197	0.006	$4s4p^4$	$^4P_{5/2}$	$4p^24f\,(^3P)$	$^4F_{7/2}$	-1.226	5.928E+08
75	817.845[d]	122272.6	817.854	-0.009	$4s^24p^3$	$^2D_{3/2}$	$4p^24d\,(^3P)$	$^2P_{1/2}$	-1.676	2.092E+08
25	822.513[d]	121578.6	822.512	0.001	$4s^24p^3$	$^2P_{3/2}$	$4p^25s\,(^3P)$	$^4P_{5/2}$	-3.201	6.205E+06
80	828.880[d]	120644.7	828.885	-0.005	$4s^24p^3$	$^2P_{1/2}$	$4s4p^4$	$^2S_{1/2}$	-1.977	1.027E+08
30	830.127[d]	120463.5	830.126	0.001	$4s^24p^3$	$^2P_{1/2}$	$4p^25s\,(^3P)$	$^4P_{3/2}$	-3.017	9.286E+06
75	835.068	119750.7	835.064	0.004	$4s4p^4$	$^4P_{3/2}$	$4p^24f\,(^3P)$	$^4F_{5/2}$	-1.170	6.437E+08
8	837.703	119374.1	837.698	0.005	$4s4p^4$	$^4P_{5/2}$	$4p^24f\,(^3P)$	$^2D_{3/2}$	-2.253	5.285E+07
85	839.112	119173.6	839.108	0.004	$4s4p^4$	$^4P_{5/2}$	$4p^24f\,(^3P)$	$^2G_{7/2}$	-1.661	2.084E+08
90	839.147[d]	119168.6	839.137	0.01	$4s^24p^3$	$^2P_{3/2}$	$4s4p^4$	$^2S_{1/2}$	-1.764	1.636E+08
52	840.407[d]	118990	840.409	-0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^25s\,(^3P)$	$^4P_{3/2}$	-2.636	2.178E+07
52	840.638[d]	118957.3	840.627	0.011	$4s^24p^3$	$^2P_{1/2}$	$4p^24d\,(^3P)$	$^4D_{1/2}$	-2.934	1.096E+07
23	841.211[d]	118876.2	841.212	-0.001	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^3P)$	$^4D_{5/2}$	-3.663	2.048E+06
95	841.456[d]	118841.6	841.451	0.005	$4s^24p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)$	$^2P_{3/2}$	-1.217	5.685E+08
30	845.952[d]	118210	845.951	0.001	$4s^24p^3$	$^2P_{1/2}$	$4p^25s\,(^3P)$	$^4P_{1/2}$	-3.118	7.088E+06
70	847.847	117945.8	847.848	-0.001	$4s4p^4$	$^4P_{5/2}$	$4p^24f\,(^3P)$	$^4D_{7/2}$	-0.589	2.403E+09
85	849.564[d]	117707.4	849.566	-0.002	$4s^24p^3$	$^2P_{3/2}$	$4p^24d\,(^3P)$	$^4D_{3/2}$	-3.048	8.261E+06
25	854.830	116982.3	854.828	0.002	$4s4p^4$	$^4P_{1/2}$	$4p^24f\,(^3P)$	$^4D_{1/2}$	-0.872	1.225E+09
45	856.326	116778	856.321	0.005	$4s4p^4$	$^4P_{3/2}$	$4p^24f\,(^3P)$	$^2D_{3/2}$	-1.182	5.950E+08
45	856.635[d]	116735.8	856.632	0.003	$4s^24p^3$	$^2P_{3/2}$	$4p^25s\,(^3P)$	$^4P_{1/2}$	-3.074	7.649E+06
85	857.960	116555.6	857.964	-0.004	$4s4p^4$	$^4P_{3/2}$	$4p^24f\,(^3P)$	$^4D_{5/2}$	-0.767	1.550E+09

73	858.674	116458.6	858.672	0.002	$4s4p^4$ $^4P_{5/2}$	$4p^24f(^3P)$ $^4G_{7/2}$	-0.618	2.184E+09
15	859.344	116367.8	859.346	-0.002	$4s4p^4$ $^4P_{5/2}$	$4p^24f(^3P)$ $^4G_{5/2}$	-2.084	7.438E+07
27	861.606	116062.3	861.597	0.009	$4s4p^4$ $^4P_{1/2}$	$4p^24f(^3P)$ $^4D_{3/2}$	-1.154	6.412E+08
43	865.109	115592.4	865.107	0.002	$4s4p^4$ $^4P_{3/2}$	$4p^24f(^3P)$ $^2D_{5/2}$	-1.147	6.343E+08
40	865.605	115526.1	865.599	0.006	$4s4p^4$ $^4P_{1/2}$	$4p^24f(^3P)$ $^2D_{3/2}$	-1.269	4.757E+08
10	878.952	113771.9	878.955	-0.003	$4s4p^4$ $^4P_{3/2}$	$4p^24f(^3P)$ $^4G_{5/2}$	-1.610	2.113E+08
55	888.221[d]	112584.6	888.229	-0.008	$4s^24p^3$ $^2P_{1/2}$	$4p^24d(^3P)$ $^4F_{3/2}$	-2.902	1.062E+07
35	892.351[d]	112063.5	892.354	-0.003	$4s^24p^3$ $^2P_{3/2}$	$4p^24d(^3P)$ $^4F_{5/2}$	-2.979	8.815E+06
30	894.329	111815.7	894.330	-0.001	$4s4p^4$ $^2D_{3/2}$	$4p^24f(^1D)$ $^2D_{3/2}$	-0.747	1.491E+09
65	906.435[d]	110322.3	906.442	-0.007	$4s^24p^3$ $^2P_{1/2}$	$4p^24d(^3P)$ $^2P_{1/2}$	-2.380	3.366E+07
85	911.769[B]	109676.9	911.771	-0.002	$4s4p^4$ $^2D_{5/2}$	$4p^24f(^1D)$ $^2F_{5/2}$	-1.272	4.253E+08
80	913.345[d]	109487.7	913.34	0.005	$4s^24p^3$ $^2D_{3/2}$	$4s4p^4$ $^2D_{5/2}$	-2.819	1.213E+07
70	916.703	109086.6	916.694	0.009	$4s4p^4$ $^2D_{5/2}$	$4p^24f(^1D)$ $^2F_{7/2}$	-0.277	4.200E+09
100	918.732[d]	108845.7	918.731	0.001	$4s^24p^3$ $^2D_{3/2}$	$4s4p^4$ $^2D_{3/2}$	-0.956	8.758E+08
100	918.732[d]	108845.7	918.716	0.016	$4s^24p^3$ $^2P_{3/2}$	$4p^24d(^3P)$ $^2P_{1/2}$	-2.410	3.059E+07
90	922.254[d]	108430	922.252	0.002	$4s^24p^3$ $^2D_{5/2}$	$4s4p^4$ $^2D_{5/2}$	-0.915	9.543E+08
50	926.349[d]	107950.7	926.349	0	$4s^24p^3$ $^2P_{1/2}$	$4p^24d(^3P)$ $^2P_{3/2}$	-2.359	3.385E+07
60	927.751[d]	107787.5	927.749	0.002	$4s^24p^3$ $^2D_{5/2}$	$4s4p^4$ $^2D_{3/2}$	-3.636	1.797E+06
30	939.165[d]	106477.6	939.172	-0.007	$4s^24p^3$ $^2P_{3/2}$	$4p^24d(^3P)$ $^2P_{3/2}$	-2.340	3.437E+07
100	949.021[d]	105371.7	949.019	0.002	$4s^24p^3$ $^4S_{3/2}$	$4s4p^4$ $^4P_{1/2}$	-1.394	2.996E+08
100	960.427[d]	104120.4	960.428	-0.001	$4s^24p^3$ $^4S_{3/2}$	$4s4p^4$ $^4P_{3/2}$	-1.084	5.960E+08
100	984.995[d]	101523.4	984.988	0.007	$4s^24p^3$ $^4S_{3/2}$	$4s4p^4$ $^4P_{5/2}$	-0.883	8.989E08
80	1007.405	99264.9	1007.410	-0.005	$4p^24d(^3P)$ $^2P_{3/2}$	$4p^24f(^1D)$ $^2F_{5/2}$	-1.252	3.661E+08
30	1008.730	99134.6	1008.731	-0.001	$4s4p^4$ $^2D_{5/2}$	$4p^24f(^3P)$ $^4F_{5/2}$	-1.822	9.818E+07
30	1016.357	98390.6	1016.361	-0.004	$4p^24d(^3P)$ $^2P_{1/2}$	$4p^24f(^1D)$ $^2D_{3/2}$	-1.340	2.971E+08
100	1032.028[d]	96896.6	1032.033	-0.005	$4s^24p^3$ $^2P_{1/2}$	$4s4p^4$ $^2D_{3/2}$	-1.605	1.559E+08
90	1040.967[d]	96064.5	1040.966	0.001	$4s^24p^3$ $^2P_{3/2}$	$4s4p^4$ $^2D_{5/2}$	-1.146	4.398E+08
60	1047.971[d]	95422.5	1047.974	-0.003	$4s^24p^3$ $^2P_{3/2}$	$4s4p^4$ $^2D_{3/2}$	-2.907	7.419E+06
70	1066.128	93797.4	1066.131	-0.003	$4s4p^4$ $^2D_{3/2}$	$4p^24f(^3P)$ $^4G_{5/2}$	-1.190	3.767E+08
5	1085.008	92165.2	1085.010	-0.002	$4p^24d(^3P)$ $^4F_{9/2}$	$4p^24f(^1D)$ $^2H_{11/2}$	-3.045	5.107E+06
10	1101.999	90744.2	1101.990	0.009	$4p^24d(^1D)$ $^2F_{5/2}$	$4p^24f(^1D)$ $^2D_{3/2}$	-1.372	2.335E+08
50	1109.213	90154.0	1109.210	0.003	$4s4p^4$ $^2S_{1/2}$	$4p^24f(^1D)$ $^2P_{1/2}$	-0.464	1.856E+09
30	1109.961	90093.3	1109.954	0.007	$4p^24d(^3P)$ $^2P_{3/2}$	$4p^24f(3P)$ $^2F_{5/2}$	-1.028	5.099E+08
30	1120.472	89248.1	1120.469	0.003	$4p^24d(^1D)$ $^2F_{5/2}$	$4p^24f(^1D)$ $^2F_{5/2}$	-0.948	5.941E+08
30	1125.220[d]	88871.5	1125.221	-0.001	$4s^24p^3$ $^2D_{3/2}$	$4s4p^4$ $^4P_{3/2}$	-3.573	1.409E+06
70	1138.771[d]	87814.0	1138.778	-0.007	$4s^24p^3$ $^2D_{5/2}$	$4s4p^4$ $^4P_{3/2}$	-3.146	3.679E+06
20	1157.809	86370.0	1157.826	-0.017	$4p^24d(^3P)$ $^4D_{5/2}$	$4p^24f(^1D)$ $^2G_{7/2}$	-0.686	1.032E+09
70	1158.910	86288.0	1158.931	-0.021	$4p^24d(^3P)$ $^2P_{3/2}$	$4p^24f(^3P)$ $^4D_{3/2}$	-0.938	5.904E+08
50	1159.086[d]	86274.9	1159.080	0.006	$4s^24p^3$ $^2D_{3/2}$	$4s4p^4$ $^4P_{5/2}$	-3.003	4.917E+06
50	1159.086	86274.9	1159.069	0.017	$4p^24d(^3P)$ $^4D_{5/2}$	$4p^24f(^1D)$ $^2F_{7/2}$	-0.640	1.138E+09
40	1164.901	85844.2	1164.894	0.007	$4p^24d(^1D)$ $^2F_{7/2}$	$4p^24f(^1D)$ $^2H_{9/2}$	-1.763	8.548E+07
25	1166.196	85748.9	1166.185	0.011	$4p^24d(^3P)$ $^2P_{3/2}$	$4p^24f(^3P)$ $^2D_{3/2}$	-1.316	2.366E+08
65	1169.209	85527.9	1169.235	-0.026	$4p^24d(^3P)$ $^2P_{3/2}$	$4p^24f(^3P)$ $^4D_{5/2}$	-0.381	2.044E+09
95	1173.469[d]	85217.4	1173.471	-0.002	$4s^24p^3$ $^2D_{5/2}$	$4s4p^4$ $^4P_{5/2}$	-2.563	1.320E+07
5	1178.472	84855.6	1178.470	0.002	$4p^25s(^3P)$ $^2P_{1/2}$	$4p^24f(^1D)$ $^2D_{3/2}$	-1.562	1.320E+08
70	1182.549	84563.1	1182.542	0.007	$4p^24d(^3P)$ $^2P_{3/2}$	$4p^24f(^3P)$ $^2D_{5/2}$	-0.164	3.283E+09

5	1190.934	83967.7	1190.937	-0.003	$4p^24d\,(^1D)\ ^2F_{7/2}$	$4p^24f\,(^1D)\ ^2F_{5/2}$	-1.438	1.696E+08
80	1191.673	83915.6	1191.674	-0.001	$4p^24d\,(^3P)\ ^2P_{1/2}$	$4p^24f\,(^3P)\ ^4D_{3/2}$	-0.404	1.912E+09
70	1199.360	83377.8	1199.349	0.011	$4p^24d\,(^1D)\ ^2F_{7/2}$	$4p^24f\,(^1D)\ ^2F_{7/2}$	-0.351	2.066E+09
70	1199.360	83377.8	1199.344	0.016	$4p^24d\,(^3P)\ ^2P_{1/2}$	$4p^24f\,(^3P)\ ^2D_{3/2}$	-0.431	1.715E+09
75	1203.357	83100.9	1203.359	-0.002	$4p^24d\,(^1D)\ ^2F_{7/2}$	$4p^24f\,(^1D)\ ^2G_{9/2}$	0.215	7.566E+09
70	1208.565	82742.8	1208.569	-0.004	$4p^24d\,(^3P)\ ^2P_{3/2}$	$4p^24f\,(^3P)\ ^4G_{5/2}$	-0.500	1.446E+09
15	1224.507	81665.5	1224.518	-0.011	$4p^24d\,(^3P)\ ^4F_{7/2}$	$4p^24f\,(^3P)\ ^4F_{7/2}$	-0.627	1.042E+09
10	1235.761	80921.8	1235.761	-0.004	$4p^24d\,(^3P)\ ^4F_{7/2}$	$4p^24f\,(^3P)\ ^4F_{9/2}$	-0.739	7.965E+08
40	1242.450	80486.1	1242.430	0.020	$4p^24d\,(^1D)\ ^2F_{5/2}$	$4p^24f\,(^3P)\ ^2F_{7/2}$	-0.546	1.228E+09
30	1248.764	80079.2	1248.787	-0.023	$4p^24d\,(^1D)\ ^2F_{5/2}$	$4p^24f\,(^3P)\ ^2F_{5/2}$	-0.629	1.005E+09
60	1250.585	79962.6	1250.582	0.003	$4p^24d\,(^3P)\ ^4F_{5/2}$	$4p^24f\,(^3P)\ ^2G_{7/2}$	-0.504	1.344E+09
65	1251.077	79931.1	1251.084	-0.007	$4p^24d\,(^3P)\ ^4F_{3/2}$	$4p^24f\,(^3P)\ ^2D_{5/2}$	-0.319	2.031E+09
85	1270.096	78734.2	1270.096	0	$4p^24d\,(^3P)\ ^4F_{5/2}$	$4p^24f\,(^3P)\ ^4D_{7/2}$	-0.040	3.771E+09
80	1270.558	78705.6	1270.548	0.01	$4p^24d\,(^1D)\ ^2F_{5/2}$	$4p^24f\,(^3P)\ ^4F_{5/2}$	-0.534	1.202E+09
80	1277.092	78302.9	1277.090	0.002	$4p^24d\,(^3P)\ ^4F_{7/2}$	$4p^24f\,(^3P)\ ^4G_{9/2}$	0.521	1.341E+10
40	1279.207[d]	78173.4	1279.206	0.001	$4s^24p^3\ ^2P_{1/2}$	$4s4p^4\ ^4P_{1/2}$	-3.463	1.406E+06
75	1280.256	78109.4	1280.252	0.004	$4p^24d\,(^3P)\ ^4F_{3/2}$	$4p^24f\,(^3P)\ ^4G_{5/2}$	0.267	7.462E+09
95	1283.518	77910.9	1283.518	0	$4p^24d\,(^3P)\ ^4F_{9/2}$	$4p^24f\,(^3P)\ ^4G_{11/2}$	0.726	2.151E+10
20	1284.060	77878.0	1284.058	0.002	$4p^24d\,(^3P)\ ^4D_{7/2}$	$4p^24f\,(^3P)\ ^2G_{9/2}$	-0.814	6.276E+08
50	1286.485	77731.2	1286.496	-0.011	$4p^24d\,(^3P)\ ^4D_{7/2}$	$4p^24f\,(^3P)\ ^4F_{7/2}$	-0.138	2.927E+09
85	1290.441	77492.9	1290.456	-0.015	$4p^24d\,(^3P)\ ^4D_{3/2}$	$4p^24f\,(^3P)\ ^4F_{5/2}$	-0.038	3.652E+09
90	1294.536	77247.8	1294.540	-0.004	$4p^24d\,(^3P)\ ^4F_{5/2}$	$4p^24f\,(^3P)\ ^4G_{7/2}$	0.266	7.328E+09
30	1294.679[w]	77239.2	1294.651	0.028	$4p^24d\,(^3P)\ ^4F_{7/2}$	$4p^24f\,(^3P)\ ^4D_{7/2}$	-0.526	1.186E+09
60	1296.075	77156	1296.072	0.003	$4p^24d\,(^3P)\ ^4F_{5/2}$	$4p^24f\,(^3P)\ ^4G_{5/2}$	-0.877	5.229E+08
30	1296.699	77118.9	1296.679	0.02	$4p^24d\,(^3P)\ ^4D_{1/2}$	$4p^24f\,(^3P)\ ^4F_{3/2}$	-0.201	2.525E+09
60	1298.926	76986.7	1298.919	0.007	$4p^24d\,(^3P)\ ^4D_{7/2}$	$4p^24f\,(^3P)\ ^4F_{9/2}$	0.524	1.327E+10
30	1300.421	76898.2	1300.426	-0.005	$4p^24d\,(^3P)\ ^4D_{3/2}$	$4p^24f\,(^3P)\ ^4F_{3/2}$	-0.331	1.861E+09
80	1309.817	76346.5	1309.842	-0.025	$4p^24d\,(^3P)\ ^4D_{5/2}$	$4p^24f\,(^3P)\ ^4F_{7/2}$	0.132	5.266E+09
8	1311.123	76270.5	1311.126	-0.003	$4p^24d\,(^1D)\ ^2F_{5/2}$	$4p^24f\,(^3P)\ ^4D_{3/2}$	-1.709	7.815E+07
95	1313.360	76140.6	1313.367	-0.007	$4p^24d\,(^1D)\ ^2G_{7/2}$	$4p^24f\,(^1D)\ ^2H_{9/2}$	0.710	1.995E+10
5	1316.214	75975.5	1316.221	-0.007	$4p^24d\,(^3P)\ ^4D_{3/2}$	$4p^24f\,(^3P)\ ^4D_{1/2}$	-1.324	1.830E+08
12	1320.062	75754	1320.059	0.003	$4p^24d\,(^3P)\ ^4F_{7/2}$	$4p^24f\,(^3P)\ ^4G_{7/2}$	-1.818	5.799E+07
80	1323.916	75533.5	1323.925	-0.009	$4p^24d\,(^1D)\ ^2F_{5/2}$	$4p^24f\,(^3P)\ ^2G_{7/2}$	0.132	5.219E+09
30	1325.428[d]	75447.3	1325.420	0.008	$4s^24p^3\ ^2P_{3/2}$	$4s4p^4\ ^4P_{3/2}$	-3.134	2.787E+06
85	1328.073	75297.1	1328.071	0.002	$4p^24d\,(^1D)\ ^2G_{9/2}$	$4p^24f\,(^1D)\ ^2H_{11/2}$	0.832	2.598E+10
25	1329.667	75206.8	1329.671	-0.004	$4p^24d\,(^1D)\ ^2F_{7/2}$	$4p^24f\,(^3P)\ ^2F_{7/2}$	-0.760	6.531E+08
10	1332.339	75056.0	1332.337	0.002	$4p^24d\,(^3P)\ ^4D_{3/2}$	$4p^24f\,(^3P)\ ^4D_{3/2}$	-1.172	2.606E+08
65	1337.942	74741.7	1337.943	-0.001	$4p^24d\,(^3P)\ ^4D_{1/2}$	$4p^24f\,(^3P)\ ^2D_{3/2}$	-0.284	1.924E+09
25	1344.651	74368.7	1344.652	-0.001	$4p^24d\,(^3P)\ ^4D_{7/2}$	$4p^24f\,(^3P)\ ^4G_{9/2}$	-0.840	5.286E+08
65	1345.990	74294.8	1345.973	0.017	$4p^24d\,(^3P)\ ^4D_{3/2}$	$4p^24f\,(^3P)\ ^4D_{5/2}$	-0.231	2.169E+09
40	1355.626	73766.7	1355.626	0	$4p^24d\,(^1D)\ ^2G_{7/2}$	$4p^24f\,(^1D)\ ^2G_{7/2}$	-0.452	1.283E+09
65	1358.773	73595.8	1358.786	-0.013	$4p^24d\,(^1D)\ ^2F_{7/2}$	$4p^24f\,(^3P)\ ^2G_{9/2}$	0.403	9.216E+09
30	1361.535	73446.5	1361.517	0.018	$4p^24d\,(^1D)\ ^2F_{7/2}$	$4p^24f\,(^3P)\ ^4F_{7/2}$	-0.573	9.596E+08
30	1362.478	73395.7	1362.468	0.01	$4p^24d\,(^1D)\ ^2G_{7/2}$	$4p^24f\,(^1D)\ ^2G_{9/2}$	-0.432	1.325E+09
65	1367.088	73148.2	1367.058	0.03	$4p^24d\,(^3P)\ ^4D_{5/2}$	$4p^24f\,(^3P)\ ^2G_{7/2}$	-0.187	2.346E+09

40	1373.288	72817.9	1373.293	-0.005	$4p^24d\,(^1D)\,^2F_{5/2}$	$4p^24f\,(^3P)\,^4G_{7/2}$	-0.251	1.989E+09
30	1378.903	72521.4	1378.903	0	$4p^24d\,(^1D)\,^2G_{9/2}$	$4p^24f\,(^1D)\,^2G_{9/2}$	-0.265	1.915E+09
60	1390.407	71921.4	1390.411	-0.004	$4p^24d\,(^3P)\,^4D_{5/2}$	$4p^24f\,(^3P)\,^4D_{7/2}$	-0.482	1.143E+09
20	1419.763	70434.3	1419.759	0.004	$4p^24d\,(^3P)\,^4D_{5/2}$	$4p^24f\,(^3P)\,^4G_{7/2}$	-1.006	3.268E+08
35	1508.033	66311.5	1508.048	-0.015	$4s4p^4\ ^2P_{3/2}$	$4p^24f\,(^1D)\,^2P_{3/2}$	-0.317	1.393E+09
10	1526.664	65502.3	1526.669	-0.005	$4p^24d\,(^1D)\,^2G_{7/2}$	$4p^24f\,(^3P)\,^2F_{7/2}$	-1.444	1.019E+08
10	1541.307	64880.0	1541.307	0	$4p^24d\,(^1D)\,^2P_{1/2}$	$4p^24f\,(^1D)\,^2P_{1/2}$	-1.174	1.863E+08
8	1562.561	63997.5	1562.545	0.016	$4s4p^4\ ^2P_{3/2}$	$4p^24f\,(^1D)\,^2D_{5/2}$	0.003	2.748E+09
20	1631.904	61278.1	1631.896	0.008	$4p^24d\,(^3P)\,^4P_{5/2}$	$4p^24f\,(^3P)\,^4F_{7/2}$	-0.436	9.186E+08
26	1632.484	61256.3	1632.485	-0.001	$4p^24d\,(^3P)\,^4P_{5/2}$	$4p^24f\,(^3P)\,^4F_{5/2}$	-0.756	4.361E+08
50	1642.338	60888.8	1642.338	0	$4p^24d\,(^3P)\,^2F_{7/2}$	$4p^24f\,(^1D)\,^2H_{9/2}$	-0.356	1.105E+09
10	1672.616	59786.6	1672.601	0.015	$4p^24d\,(^1D)\,^2D_{5/2}$	$4p^24f\,(^1D)\,^2P_{3/2}$	-0.670	5.083E+08
5	1694.585	59011.5	1694.582	0.003	$4p^24d\,(^3P)\,^2F_{7/2}$	$4p^24f\,(^1D)\,^2F_{5/2}$	-1.280	1.203E+08
10	1696.678	58938.7	1696.683	-0.005	$4p^24d\,(^3P)\,^4P_{1/2}$	$4p^24f\,(^3P)\,^4F_{3/2}$	-0.968	2.513E+08
80	1702.333	58742.9	1702.331	0.002	$4p^24d\,(^3P)\,^2F_{5/2}$	$4p^24f\,(^1D)\,^2G_{7/2}$	0.321	4.884E+09
20	1711.662	58422.7	1711.664	-0.002	$4p^24d\,(^3P)\,^2F_{7/2}$	$4p^24f\,(^1D)\,^2F_{7/2}$	-0.186	1.488E+09
10	1715.728	58284.3	1715.746	-0.018	$4p^24d\,(^3P)\,^4P_{5/2}$	$4p^24f\,(^3P)\,^2D_{3/2}$	-1.680	4.694E+07
40	1719.84	58144.9	1719.844	-0.004	$4p^24d\,(^3P)\,^2F_{7/2}$	$4p^24f\,(^1D)\,^2G_{9/2}$	0.399	5.678E+09
25	1722.367	58059.6	1722.356	0.011	$4p^24d\,(^3P)\,^4P_{5/2}$	$4p^24f\,(^3P)\,^4D_{5/2}$	-0.510	6.990E+08
15	1723.675	58015.6	1723.670	0.005	$4p^24d\,(^3P)\,^4P_{1/2}$	$4p^24f\,(^3P)\,^4D_{1/2}$	-0.135	1.643E+09
20	1730.769	57777.8	1730.760	0.009	$4p^24d\,(^3P)\,^4P_{3/2}$	$4p^24f\,(^3P)\,^4D_{3/2}$	-0.281	1.210E+09
60	1737.955	57538.9	1737.952	0.003	$4p^24d\,(^3P)\,^2D_{3/2}$	$4p^24f\,(^3P)\,^2F_{5/2}$	0.208	3.567E+09
70	1739.895	57474.7	1739.906	-0.011	$4p^24d\,(^1D)\,^2D_{5/2}$	$4p^24f\,(^1D)\,^2D_{5/2}$	-0.084	1.837E+09
52	1746.996	57241.1	1746.987	0.009	$4p^24d\,(^3P)\,^4P_{3/2}$	$4p^24f\,(^3P)\,^2D_{3/2}$	-0.508	6.718E+08
60	1753.827	57018.2	1753.841	-0.014	$4p^24d\,(^3P)\,^4P_{3/2}$	$4p^24f\,(^3P)\,^4D_{5/2}$	-0.168	1.474E+09
47	1768.034	56560.0	1768.033	0.001	$4p^24d\,(^3P)\,^4P_{1/2}$	$4p^24f\,(^3P)\,^2D_{3/2}$	-0.590	5.413E+08
30	1777.403	56261.9	1777.405	-0.002	$4p^24d\,(^1D)\,^2D_{3/2}$	$4p^24f\,(^1D)\,^2F_{5/2}$	0.144	2.894E+09
70	1793.340	55761.9	1793.342	-0.002	$4p^24d\,(^1D)\,^2D_{5/2}$	$4p^24f\,(^1D)\,^2F_{5/2}$	-0.754	3.621E+08
68	1800.319	55545.7	1800.323	-0.004	$4p^24d\,(^3P)\,^2D_{5/2}$	$4p^24f\,(^3P)\,^2F_{7/2}$	0.512	6.636E+09
40	1806.105	55367.8	1806.104	0.001	$4p^24d\,(^3P)\,^4P_{5/2}$	$4p^24f\,(^3P)\,^4G_{7/2}$	-0.190	1.327E+09
45	1809.451	55265.4	1809.448	0.003	$4p^24d\,(^1D)\,^2D_{5/2}$	$4p^24f\,(^1D)\,^2G_{7/2}$	-0.219	1.252E+09
33	1812.481	55173.0	1812.485	-0.004	$4p^24d\,(^1D)\,^2D_{5/2}$	$4p^24f\,(^1D)\,^2F_{7/2}$	0.204	3.281E+09
5	1813.710	55135.6	1813.700	0.010	$4p^24d\,(^3P)\,^2D_{5/2}$	$4p^24f\,(^3P)\,^2F_{5/2}$	-0.668	4.332E+08
70	1825.491	54779.8	1825.493	-0.002	$4p^24d\,(^1D)\,^2P_{3/2}$	$4p^24f\,(^1D)\,^2D_{5/2}$	0.047	2.208E+09
30	1861.097	53731.75	1861.102	-0.005	$4p^24d\,(^3P)\,^2D_{3/2}$	$4p^24f\,(^3P)\,^4D_{3/2}$	-1.192	1.291E+08
100	1884.406	53067.1	1884.404	0.002	$4p^24d\,(^1D)\,^2P_{3/2}$	$4p^24f\,(^1D)\,^2F_{5/2}$	-0.529	5.388E+08
65	1976.624	50591.31	1976.628	-0.004	$4p^24d\,(^3P)\,^2D_{5/2}$	$4p^24f\,(^3P)\,^2G_{7/2}$	-0.120	1.307E+09

10	1997.252	50068.79	1997.255	-0.003	4p^{2}4d (^{3}P) ^{2}F$_{5/2}$	4p^{2}4f (^{3}P) ^{2}F$_{5/2}$	-0.709	3.278E+08
	λ_{obs} in air(Å)[e]		λ_{Ritz} in air(Å					
55	1999.639	49992.82	1999.632	0.007	4p^{2}4d (^{1}D) ^{2}S$_{1/2}$	4p^{2}4f (^{1}D) ^{2}P$_{3/2}$	-0.081	1.389E+09
25	2000.118	49980.86	2000.117	0.001	4p^{2}4d (^{1}S) ^{2}D$_{5/2}$	4p^{2}4f (^{1}D) ^{2}D$_{5/2}$	-0.703	3.318E+08
60	2017.473	49550.97	2017.473	0	4p^{2}4d (^{1}D) ^{2}S$_{1/2}$	4p^{2}4f (^{1}D) ^{2}P$_{1/2}$	-0.081	1.389E+09
40	2055.304	48639.03	2055.296	0.008	4p^{2}4d (^{3}P) ^{2}F$_{7/2}$	4p^{2}4f (^{3}P) ^{2}G$_{9/2}$	0.467	4.708E+09
30	2092.611	47772.01	2092.612	-0.001	4p^{2}4d (^{1}S) ^{2}D$_{5/2}$	4p^{2}4f (^{1}D) ^{2}G$_{7/2}$	-0.071	1.308E+09
25	2093.65	47748.31	2093.653	-0.003	4p^{2}4d (^{3}P) ^{2}F$_{7/2}$	4p^{2}4f (^{3}P) ^{4}F$_{9/2}$	-0.018	1.472E+09

[B] blended with other line, [W] wide line.

[a] Intensity figures are visual estimates of photographic blackening.

[b] Observed wavelengthvalue - calculated value from Table 3.2.

[c] Transition probabilities(gA) obtained by Cowan's code. Here g is the statistical weight of the upper level while for gf, g refers to the weight of the lower level.

[d] Lines originally classified by Jabeen and Tauheed [6].

[e] lines 2000Å- 2400Å were taken from Ref. [10].

Table 3.1B: Classified lines of Br III in the [(4s4p^4+4p^{2}nd + 4p^{2}ns) – 4p^{2}5p] transition array.

I_{obs}[a]	λ_{obs}(Å)	σ_{obs}(cm^{-1})	λ_{Ritz}(Å)	λ_{obs}- λ_{Ritz} (Å)[b]	Lower level		Upper level	Log gf	gA(s^{-1})[c]
30	1270.315	78720.6	1270.311	0.004	4s4p^4	$^4P_{5/2}$	4p^{2}5p (^{3}P) $^4S_{3/2}$	-1.270	2.231E+08
5	1280.657	78084.9	1280.666	-0.009	4s4p^4	$^4P_{3/2}$	4p^{2}5p (^{3}P) $^2D_{5/2}$	-2.120	3.093E+07
65	1284.687	77840.0	1284.687	0	4s4p^4	$^4P_{5/2}$	4p^{2}5p (^{3}P) $^4P_{5/2}$	-1.521	1.203E+08
40	1302.256[c]	76789.8	1302.259	-0.003	4s4p^4	$^4P_{5/2}$	4p^{2}5p (^{3}P) $^4D_{7/2}$	-1.781	6.521E+07
45	1305.539	76596.7	1305.531	0.008	4s4p^4	$^4P_{5/2}$	4p^{2}5p (^{3}P) $^2D_{3/2}$	-1.393	1.600E+08
65	1313.644	76124.1	1313.633	0.011	4s4p^4	$^4P_{3/2}$	4p^{2}5p (^{3}P) $^4S_{3/2}$	-1.033	3.591E+08
60	1330.888	75137.8	1330.891	-0.003	4s4p^4	$^4P_{5/2}$	4p^{2}5p (^{3}P) $^4P_{3/2}$	-1.110	2.935E+08
10	1351.332	74001.1	1351.331	0.001	4s4p^4	$^4P_{3/2}$	4p^{2}5p (^{3}P) $^2D_{3/2}$	-1.926	4.360E+07
20	1378.519	72541.6	1378.521	-0.002	4s4p^4	$^4P_{3/2}$	4p^{2}5p (^{3}P) $^4P_{3/2}$	-1.873	4.703E+07
8	1382.996[c]	72306.8	1382.996	0	4s4p^4	$^4P_{5/2}$	4p^{2}5p (^{3}P) $^4D_{5/2}$	-1.749	6.212E+07
20	1384.583	72223.9	1384.570	0.013	4s4p^4	$^2D_{5/2}$	4p^{2}5p (^{1}D) $^2P_{3/2}$	-1.002	3.453E+08
5	1448.184	69052.0	1448.169	0.015	4s4p^4	$^4P_{3/2}$	4p^{2}5p (^{3}P) $^4D_{1/2}$	-3.271	1.791E+06
5	1460.728	68459.0	1460.731	-0.003	4s4p^4	$^4P_{1/2}$	4p^{2}5p (^{3}P) $^4D_{3/2}$	-2.996	3.140E+06
45	1474.691[W]	67810.8	1474.718	-0.027	4s4p^4	$^2D_{3/2}$	4p^{2}5p (^{1}D) $^2D_{3/2}$	-0.787	4.974E+08
75	1511.120	66176.1	1511.120	0	4s4p^4	$^2D_{5/2}$	4p^{2}5p (^{1}D) $^2F_{5/2}$	-0.942	3.320E+08
33	1686.562	59292.2	1686.564	-0.002	4s4p^4	$^2D_{3/2}$	4p^{2}5p (^{3}P) $^2P_{1/2}$	-1.802	3.725E+07
5	1694.495	59014.6	1694.501	-0.006	4s4p^4	$^2D_{5/2}$	4p^{2}5p (^{3}P) $^2P_{3/2}$	-1.230	1.356E+08
35	1755.526	56963.0	1755.515	0.011	4p^{2}4d (^{3}P)	$^2P_{3/2}$	4p^{2}5p (^{1}D) $^2D_{5/2}$	-1.210	1.346E+08
80	1761.954[W]	56755.2	1761.960	-0.006	4p^{2}4d (^{3}P)	$^2P_{3/2}$	4p^{2}5p (^{1}D) $^2D_{3/2}$	-2.081	1.792E+07
38	1830.596	54627.02	1830.595	0.001	4s4p^4	$^2D_{5/2}$	4p^{2}5p (^{3}P) $^4P_{5/2}$	-1.606	4.839E+07
5	1873.230	53383.73	1873.210	0.020	4s4p^4	$^2D_{5/2}$	4p^{2}5p (^{3}P) $^2D_{3/2}$	-2.139	1.396E+07
3	1902.334	52567.0	1902.329	0.005	4s4p^4	$^2D_{3/2}$	4p^{2}5p (^{3}P) $^4P_{3/2}$	-2.184	1.203E+07
15	1954.507	51163.8	1954.496	0.011	4s4p^4	$^2D_{5/2}$	4p^{2}5p (^{3}P) $^4D_{5/2}$	-2.895	2.215E+06
	λ_{obs} in air(Å)		λ_{Ritz} in air(Å)						
2	2009.935	49736.8	2009.955	-0.019	4s4p^4	$^2D_{3/2}$	4p^{2}5p (^{3}P) $^4D_{3/2}$	-2.865	2.230E+06
40	2017.473[B]	49551.0	2017.514	-0.041	4p^{2}5p (^{3}P)	$^4D_{7/2}$	4p^{2}5d (^{1}D) $^2F_{7/2}$	-2.789	2.661E+06
15	2019.139	49510.1	2019.195	-0.056	4p^{2}5s (^{3}P)	$^4P_{1/2}$	4p^{2}5p (^{1}D) $^2P_{1/2}$	-0.935	2.976E+07
25	2035.216	49119.0	2035.209	0.006	4s4p^4	$^2S_{1/2}$	4p^{2}5p (^{1}D) $^2P_{3/2}$	-1.108	1.236E+08
3	2036.258	49093.9	2036.259	0	4s4p^4	$^2D_{5/2}$	4p^{2}5p (^{3}P) $^4D_{3/2}$	-2.433	5.913E+06
25	2056.824	48603.1	2056.860	-0.037	4p^{2}4d (^{3}P)	$^2P_{3/2}$	4p^{2}5p (^{3}P) $^2P_{3/2}$	-0.993	1.605E+08
60	2060.014	48527.8	2060.066	-0.052	4p^{2}5p (^{3}P)	$^2S_{1/2}$	4p^{2}5d (^{3}P) $^2P_{1/2}$	-0.691	3.205E+08
5	2086.548	47910.8	2086.569	-0.021	4p^{2}5p (^{3}P)	$^2S_{1/2}$	4p^{2}5d (^{3}P) $^4P_{1/2}$	-2.871	2.046E+06
40	2118.472	47188.9	2118.554	-0.082	4s4p^4	$^2D_{3/2}$	4p^{2}5p (^{3}P) $^2S_{1/2}$	-1.567	4.007E+07
30	2120.521	47143.3	2120.541	-0.02	4p^{2}5p (^{3}P)	$^2P_{3/2}$	4p^{2}5d (^{1}D) $^2D_{5/2}$	-1.603	3.754E+07
15	2129.371	46947.4	2129.386	-0.016	4p^{2}4d (^{1}D)	$^2F_{5/2}$	4p^{2}5p (^{1}D) $^2D_{5/2}$	-1.303	7.319E+07
25	2138.830	46739.8	2138.881	-0.051	4p^{2}4d (^{1}D)	$^2F_{5/2}$	4p^{2}5p (^{1}D) $^2D_{3/2}$	-1.519	4.408E+07
20	2162.199	46234.69	2162.263	-0.064	4p^{2}5p (^{3}P)	$^2S_{1/2}$	4p^{2}6s (^{3}P) $^2P_{3/2}$	-1.212	8.728E+07
30	2179.605	45865.5	2179.547	0.058	4p^{2}4d (^{3}P)	$^2P_{1/2}$	4p^{2}5p (^{3}P) $^2P_{1/2}$	-1.252	8.069E+07
10	2185.161	45748.9	2185.222	-0.061	4p^{2}4d (^{1}D)	$^2F_{5/2}$	4p^{2}5p (^{1}D) $^2F_{5/2}$	-1.182	9.113E+07
25	2227.426	44880.91	2227.356	0.071	4p^{2}4d (^{3}P)	$^4D_{7/2}$	4p^{2}5p (^{1}D) $^2F_{7/2}$	-1.024	1.307E+08

5	2249.017	44450.1	2249.004	0.012	$4p^25s\,(^3P)\,^4P_{3/2}$	$4p^25p\,(^1D)\,^2D_{5/2}$	-2.247	7.461E+06
10	2253.804	44355.69	2253.805	-0.001	$4p^24d\,(^3P)\,^4D_{5/2}$	$4p^25p\,(^1D)\,^2D_{3/2}$	-1.480	4.325E+07
20	2279.096	43863.5	2279.126	-0.03	$4p^25s\,(^3P)\,^2P_{1/2}$	$4p^25p\,(^1D)\,^2P_{1/2}$	-1.544	3.717E+07
10	2298.322	43496.6	2298.305	0.017	$4p^24d\,(^3P)\,^4D_{5/2}$	$4p^25p\,(^1D)\,^2F_{7/2}$	-1.982	1.353E+07
10	2305.261	43365.7	2305.319	-0.058	$4p^24d\,(^3P)\,^4D_{5/2}$	$4p^25p\,(^1D)\,^2F_{5/2}$	-1.829	1.843E+07
10	2319.151	43105.99	2319.145	0.006	$4p^25s\,(^3P)\,^2P_{3/2}$	$4p^25p\,(^1D)\,^2P_{3/2}$	-0.792	1.994E+08
50	2447.218	40850.4	2447.253	-0.035	$4p^25s\,(^3P)\,^2P_{1/2}$	$4p^25p\,(^1D)\,^2D_{3/2}$	-0.787	1.812E+08
40	2462.352	40599.3	2462.356	-0.004	$4p^24d\,(^1D)\,^2F_{7/2}$	$4p^25p\,(^1D)\,^2F_{7/2}$	-0.572	3.029E+08
30	2498.402	40013.52	2498.371	0.03	$4p^24d\,(^3P)\,^2D_{5/2}$	$4p^25p\,(^1S)\,^2P_{3/2}$	-0.858	1.470E+08
30	2498.402[d]	40013.52	2498.378	0.024	$4p^25p\,(^3P)\,^4D_{5/2}$	$4p^26s\,(^3P)\,^4P_{5/2}$	-2.162	7.973E+06
50	2613.104	38257.24	2613.118	-0.014	$4p^25s\,(^3P)\,^2P_{3/2}$	$4p^25p\,(^1D)\,^2D_{5/2}$	-0.547	2.771E+08
30	2616.210	38211.8	2616.210	0	$4p^25p\,(^3P)\,^4D_{7/2}$	$4p^25d\,(^3P)\,^4F_{9/2}$	0.842	6.811E+09
20	2629.202	38023.02	2629.153	0.049	$4p^24d\,(^3P)\,^2P_{3/2}$	$4p^25p\,(^3P)\,^4D_{1/2}$	-1.162	6.742E+07
30	2677.340	37339.4	2677.34	0	$4p^25p(^1D)^2F_{7/2}$	$4p^25d\,(^1D)\,^2G_{9/2}$	0.831	6.108E+09
40	2694.218[d]	37105.5	2694.167	0.051	$4p^25p\,(^3P)\,^4D_{5/2}$	$4p^26s\,(^3P)\,^4P_{3/2}$	0.053	1.047E+09
50	2759.892	36222.61	2759.961	-0.069	$4p^25p\,(^3P)\,^2D_{5/2}$	$4p^25d\,(^3P)\,^4D_{5/2}$	-0.194	5.517E+08
50	2766.725	36133.15	2766.776	-0.051	$4p^24d\,(^3P)\,^2P_{3/2}$	$4p^25p\,(^3P)\,^2S_{1/2}$	-0.502	2.789E+07
10	2767.862[e]	36118.31	2767.809	0.052	$4p^24d\,(^3P)\,^4F_{3/2}$	$4p^25p\,(^3P)\,^4D_{5/2}$	-2.061	7.472E+06
30	2802.619	35670.4	2802.647	-0.028	$4p^25p\,(^3P)\,^4S_{3/2}$	$4p^26s\,(^3P)\,^4P_{5/2}$	-0.021	8.060E+08
40	2842.889	35165.14	2842.853	0.036	$4p^24d\,(^3P)\,^4F_{5/2}$	$4p^25p\,(^3P)\,^4D_{5/2}$	-0.765	1.397E+08
10	2849.831	35079.5	2849.832	-0.001	$4p^24d\,(^1D)\,^2F_{5/2}$	$4p^25p\,(^3P)\,^4S_{3/2}$	-2.261	4.551E+06
30	2910.635	34346.7	2910.661	-0.025	$4p^24d\,(^3P)\,^4P_{5/2}$	$4p^25p\,(^1D)\,^2P_{3/2}$	-0.703	1.553E+08
100	2926.862	34156.3	2926.862	0	$4p^24d\,(^3P)\,^4F_{9/2}$	$4p^25p\,(^3P)\,^4D_{7/2}$	0.268	1.420E+09
50	2936.158[e]	34048.15	2936.103	0.055	$4p^24d\,(^3P)\,^4F_{3/2}$	$4p^25p\,(^3P)\,^4D_{3/2}$	-0.796	1.220E+08
90	2968.943	33672.19	2968.934	0.009	$4p^24d\,(^3P)\,^4F_{7/2}$	$4p^25p\,(^3P)\,^4D_{5/2}$	0.134	1.014E+09
90	2993.920[e]	33391.29	2993.961	-0.041	$4p^24d\,(^3P)\,^4F_{3/2}$	$4p^25p\,(^3P)\,^4D_{1/2}$	-0.363	3.205E+08
70	3020.645	33095.87	3020.689	-0.044	$4p^24d\,(^3P)\,^4F_{5/2}$	$4p^25p\,(^3P)\,^4D_{3/2}$	-0.057	6.318E+08
40	3033.517	32955.44	3033.481	0.036	$4p^24d\,(^1D)\,^2F_{5/2}$	$4p^25p\,(^3P)\,^2D_{3/2}$	-0.603	1.852E+08
50	3056.060	32712.35	3056.027	0.033	$4p^25s\,(^3P)\,^4P_{1/2}$	$4p^25p\,(^3P)\,^2D_{3/2}$	-1.178	4.849E+07
50	3056.060	32712.35	3056.102	-0.042	$4p^25s\,(^1S)\,^2S_{1/2}$	$4p^25p\,(^1S)\,^2P_{3/2}$	0.174	1.077E+09
50	3057.510	32696.85	3057.493	0.017	$4p^25s\,(^3P)\,^2P_{1/2}$	$4p^25p\,(^3P)\,^2P_{3/2}$	-0.476	2.360E+08
30	3068.203	32582.90	3068.216	-0.013	$4p^25s\,(^3P)\,^4P_{3/2}$	$4p^25p\,(^3P)\,^4S_{3/2}$	-1.006	7.068E+07
50	3091.865	32333.55	3091.966	-0.1	$4p^25s\,(^1S)\,^2S_{1/2}$	$4p^25p\,(^1S)\,^2P_{1/2}$	-0.143	5.087E+08
60	3147.806	31758.96	3147.862	-0.055	$4p^24d\,(^1D)\,^2F_{7/2}$	$4p^25p\,(^3P)\,^2D_{5/2}$	-0.018	6.501E+08
80	3174.080	31496.08	3174.063	0.017	$4p^24d\,(^1D)\,^2F_{5/2}$	$4p^25p\,(^3P)\,^4P_{3/2}$	-0.415	2.571E+08
40	3198.733	31253.34	3198.755	-0.021	$4p^25s\,(^3P)\,^4P_{1/2}$	$4p^25p\,(^3P)\,^4P_{3/2}$	-0.414	2.529E+08
40	3249.849	30761.79	3249.774	0.075	$4p^24d\,(^1D)\,^2G_{7/2}$	$4p^25p\,(^1D)\,^2F_{5/2}$	0.051	6.920E+08
30	3252.530	30736.43	3252.473	0.057	$4p^25s\,(^1D)\,^2D_{3/2}$	$4p^25p\,(^1D)\,^2D_{3/2}$	-0.149	4.309E+09
40	3269.928	30572.9	3269.938	-0.009	$4p^24d\,(^3P)\,^4D_{5/2}$	$4p^25p\,(^3P)\,^2D_{3/2}$	-0.381	2.654E+08
50	3282.086	30459.65	3282.144	-0.058	$4p^25s\,(^3P)\,^4P_{3/2}$	$4p^25p\,(^3P)\,^2D_{3/2}$	-0.616	1.537E+08
90	3333.053	29993.89	3333.068	-0.015	$4p^25s\,(^3P)\,^4P_{5/2}$	$4p^25p\,(^3P)\,^4S_{3/2}$	0.224	1.017E+09
20	3329.977	30021.6	3330.052	-0.074	$4p^24d\,(^1D)\,^2G_{9/2}$	$4p^25p\,(^1D)\,^2F_{7/2}$	0.270	1.179E+09
100	3349.636	29845.41	3349.578	0.058	$4p^25s\,(^1D)\,^2D_{5/2}$	$4p^25p\,(^1D)\,^2F_{7/2}$	0.315	1.229E+09
60	3385.236	29531.56	3385.274	-0.038	$4p^25s\,(^3P)\,^2P_{3/2}$	$4p^25p\,(^3P)\,^2P_{1/2}$	-0.496	1.903E+08
50	3424.784	29190.55	3424.783	0.001	$4p^25s\,(^3P)\,^2P_{1/2}$	$4p^25p\,(^3P)\,^4S_{3/2}$	-1.652	1.283E+07
50	3433.925	29112.85	3433.925	0	$4p^25s\,(^3P)\,^4P_{5/2}$	$4p^25p\,(^3P)\,^4P_{5/2}$	0.200	8.677E+08

90	3447.349	28999.49	3447.344	0.005	$4p^2 5s\,(^3P)\,^4P_{3/2}$	$4p^2 5p\,(^3P)\,^4P_{3/2}$	-0.065	4.881E+08
30	3476.879	28753.2	3476.782	0.097	$4s4p^4\;^2P_{1/2}$	$4p^2 5p\,(^1S)\,^2P_{1/2}$	-1.538	1.604E+07
80	3487.567	28665.08	3487.527	0.04	$4p^2 4d\,(^1D)\,^2F_{5/2}$	$4p^2 5p\,(^3P)\,^4D_{3/2}$	0.038	5.873E+08
90	3517.347[d]	28422.39	3517.360	-0.012	$4p^2 5s\,(^3P)\,^4P_{1/2}$	$4p^2 5p\,(^3P)\,^4D_{3/2}$	0.038	5.873E+08
40	3526.030	28352.4	3526.007	0.023	$4p^2 4d\,(^3P)\,^4D_{5/2}$	$4p^2 5p\,(^3P)\,^4D_{5/2}$	-1.036	4.917E+07
100	3540.151[d]	28239.31	3540.204	-0.053	$4p^2 5s\,(^3P)\,^4P_{3/2}$	$4p^2 5p\,(^3P)\,^4D_{5/2}$	0.343	1.170E+09
100	3562.431[d]	28062.71	3562.451	-0.021	$4p^2 5s\,(^3P)\,^4P_{5/2}$	$4p^2 5p\,(^3P)\,^4D_{7/2}$	0.501	1.670E+09
30	3587.073	27869.93	3587.050	0.024	$4p^2 5s\,(^3P)\,^4P_{5/2}$	$4p^2 5p\,(^3P)\,^2D_{3/2}$	-1.861	7.332E+06
90	3600.696[d]	27764.49	3600.716	-0.021	$4p^2 5s\,(^3P)\,^4P_{1/2}$	$4p^2 5p\,(^3P)\,^4D_{1/2}$	-0.358	2.268E+08
10	3673.653	27213.11	3673.625	0.028	$4p^2 4d\,(^3P)\,^2D_{3/2}$	$4p^2 5p\,(^1D)\,^2P_{1/2}$	-0.486	1.647E+08
100	3693.470	27067.11	3693.497	-0.027	$4p^2 5s\,(^3P)\,^2P_{1/2}$	$4p^2 5p\,(^3P)\,^2D_{3/2}$	-0.021	4.784E+08
40	3782.219	26432.0	3782.219	0	$4p^2 5s\,(^3P)\,^2P_{1/2}$	$4p^2 5p\,(^3P)\,^4P_{1/2}$	-1.220	2.812E+07
90	3820.259[d]	26168.81	3820.276	-0.018	$4p^2 5s\,(^3P)\,^4P_{3/2}$	$4p^2 5p\,(^3P)\,^4D_{3/2}$	-0.491	1.475E+08
50	3897.531[d]	25650.0	3897.548	-0.017	$4p^2 5s\,(^3P)\,^4P_{5/2}$	$4p^2 5p\,(^3P)\,^4D_{5/2}$	-0.822	6.598E+07
40	3918.829[d]	25510.6	3918.809	0.02	$4p^2 5s\,(^3P)\,^4P_{3/2}$	$4p^2 5p\,(^3P)\,^4D_{1/2}$	-0.877	5.802E+07
10	4239.742[d]	23579.7	4239.744	-0.002	$4p^2 5s\,(^3P)\,^4P_{5/2}$	$4p^2 5p\,(^3P)\,^4D_{3/2}$	-2.218	2.244E+06
50	4519.813	22118.61	4519.829	-0.016	$4p^2 5s\,(^3P)\,^2P_{1/2}$	$4p^2 5p\,(^3P)\,^4D_{1/2}$	-1.043	2.976E+07

[W] *wide line,* [B] *blended line with other line.*

[a] Intensity figures are visual estimates of photographic blackening.

[b] Observed wavelength value - calculated value from Table 3.2.

[c] Transition probabilities(gA) obtained by Cowan's code. Here g is the statistical weight of the upper level while for gf, g refers to the weight of the lower level.

[d] Lines originally classified by Rao and Krishnamurty [1].

[e] Lines originally classified by Bhupala Rao [3].

Table 3.2: Observed energy levels of Br III.

Designation[x]	Energy(cm^{-1})	$D_1(cm^{-1})^a$	$D_2(cm^{-1})^b$	$D_3(cm^{-1})^c$	No. of connecting lines[y]
$4s^24p^3$ $^4S_{3/2}$	0[d]	0.09	0		51
$4s^24p^3$ $^2D_{3/2}$	15248.8[d]	0.2	0.2		61
$4s^24p^3$ $^2D_{5/2}$	16306.8[d]	0.2	0.2		54
$4s^24p^3$ $^2P_{1/2}$	27198.5[d]	0.3	0.2		40
$4s^24p^3$ $^2P_{3/2}$	28672.4[d]	0.2	0.2		57
$4s4p^4$ $^4P_{5/2}$	101524.2[d]	0.2	0.3		9
$4s4p^4$ $^4P_{3/2}$	104120.2[d]	0.2	0.2		9
$4s4p^4$ $^4P_{1/2}$	105372.1[d]	0.3	0.3		7
$4s4p^4$ $^2D_{3/2}$	124094.6[d]	0.3	0.3		6
$4s4p^4$ $^2D_{5/2}$	124737.0[d]	0.3	0.3		7
$4p^24d$ (^3P) $^2P_{3/2}$	135149.2[d]	0.3	0.2		10
$4p^24d$ (^3P) $^2P_{1/2}$	137520.0[d]	0.3	0.3		6
$4p^24d$ (^3P) $^4F_{3/2}$	139782.2[d]	0.3	0.3		5
$4p^24d$ (^3P) $^4F_{5/2}$	140735.6[d]	0.2	0.2		8
$4p^24d$ (^3P) $^4F_{7/2}$	142228.8[d]	0.3	0.3		6
$4p^24d$ (^3P) $^4F_{9/2}$*	144157.5	0.1	0.1		1
$4p^24d$ (^1D) $^2F_{5/2}$	145165.3[d]	0.3	0.2		10
$4p^25s$ (^3P) $^4P_{1/2}$	145408.6[d]	0.4	0.4		4
$4p^24d$ (^3P) $^4D_{1/2}$	146157.3[d]	0.4	0.3		5
$4p^24d$ (^3P) $^4D_{7/2}$	146163.1[d]	0.3	0.3		5
$4p^24d$ (^3P) $^4D_{3/2}$	146379.6[d]	0.3	0.2		9
$4p^24d$ (^3P) $^4D_{5/2}$	147548.6[d]	0.3	0.2		10
$4p^25s$ (^3P) $^4P_{3/2}$	147662.2[d]	0.4	0.4		5
$4s4p^4$ $^2S_{1/2}$	147842.5[d]	0.4	0.4		5
$4p^25s$ (^3P) $^4P_{5/2}$	150251.3[d]	0.6	0.5		4
$4p^24d$ (^1D) $^2F_{7/2}$	150446.2[d]	0.3	0.2		8
$4p^25s$ (^3P) $^2P_{1/2}$	151054.4[d]	0.3	0.4		5
$4p^25s$ (^3P) $^2P_{3/2}$	153855.5[d]	0.6	0.5		5
$4p^24d$ (^1D) $^2G_{7/2}$	160150.7[d]	0.2	0.3		5
$4p^24d$ (^1D) $^2G_{9/2}$*	161025.0	0.2	0.3		2
$4p^25s$ (^1D) $^2D_{3/2}$	161167.3[d]	1	0.7		3
$4p^25s$ (^1D) $^2D_{5/2}$	161199.5[d]	0.7	0.6		4
$4p^24d$ (^3P) $^4P_{5/2}$	162615.2[d]	0.2	0.2		8
$4p^24d$ (^3P) $^4P_{3/2}$	163657.6[d]	0.2	0.2		8
$4p^24d$ (^3P) $^4P_{1/2}$	164338.9[d]	0.11	0.2		6
$4p^24d$ (^3P) $^2D_{3/2}$	167704.0[d]	0.2	0.2		7
$4p^24d$ (^3P) $^2D_{5/2}$	170107.1[d]	0.13	0.2		7
$4p^25p$ (^3P) $^2S_{1/2}$	171281.7	0.5	0.13	0.4	5
$4s4p^4$ $^2P_{3/2}$	172128.1[d]	0.5	0.3		7
$4p^24d$ (^1D) $^2P_{1/2}$	173116.8[d]	0.2	0.4		5
$4p^25p$ (^3P) $^4D_{1/2}$	173172.9[g]	0.08	0.09	0.3	6
$4p^25p$ (^3P) $^4D_{3/2}$	173830.9[g]	0.07	0.09	0.3	10

$4p^2 4d\ (^3P)\ ^2F_{5/2}$	175174.3[d]	0.11	0.2		6
$4p^2 4d\ (^3P)\ ^2F_{7/2}$	175402.0[d]	0.08	0.2		7
$4p^2 5p\ (^3P)\ ^4D_{5/2}$	175901.1[g]	0.12	0.09	0.3	9
$4p^2 5p\ (^3P)\ ^4P_{3/2}$[f]	176661.7[g]	0.09	0.1	0.3	6
$4p^2 5s\ (^1S)\ ^2S_{1/2}$	177409.2[d]	0.7	0.7		3
$4p^2 5p\ (^3P)\ ^4P_{1/2}$	177486.4	0.06	0.11		1
$4p^2 5p\ (^3P)\ ^2D_{3/2}$[f]	178121.3[g]	0.12	0.09	0.3	9
$4p^2 4d\ (^1D)\ ^2D_{3/2}$	178151.8[d]	0.2	0.3		6
$4p^2 5p\ (^3P)\ ^4D_{7/2}$	178313.7[g]	0.2	0.11	0.3	3
$4p^2 4d\ (^1D)\ ^2D_{5/2}$	178651.8[d]	0.13	0.2		9
$4p^2 5p\ (^3P)\ ^4P_{5/2}$	179364.1	0.06	0.11	0.3	3
$4s4p^4\ ^2P_{1/2}$	180987.7[d]	1.1	0.8		3
$4p^2 5p\ (^3P)\ ^4S_{3/2}$[f]	180245.0[g]	0.06	0.1	0.3	7
$4p^2 4d\ (^1D)\ ^2P_{3/2}$	181346.5[d]	0.12	0.3		6
$4p^2 5p\ (^3P)\ ^2D_{5/2}$[f]	182204.6[h]	0.5	0.2	0.4	3
$4p^2 5p\ (^3P)\ ^2P_{1/2}$	183386.7	0.3	0.14	0.4	3
$4p^2 5p\ (^3P)\ ^2P_{3/2}$	183751.4	0.2	0.12	0.3	4
$4p^2 4d\ (^1S)\ ^2D_{5/2}$	186145.3[d]	0.09	0.2		4
$4p^2 4d\ (^1S)\ ^2D_{3/2}$	186939.2[d]	0.8	0.7		4
$4p^2 4d\ (^1D)\ ^2S_{1/2}$	188445.8[d]	0.12	0.4		3
$4p^2 5p\ (^1D)\ ^2F_{5/2}$	190913.1	0.5	0.12	0.3	4
$4p^2 5p\ (^1D)\ ^2F_{7/2}$	191045.4	0.3	0.13	0.4	5
$4p^2 5p\ (^1D)\ ^2D_{3/2}$[f]	191904.2[i]	0.3	0.11	0.3	6
$4p^2 5p\ (^1D)\ ^2D_{5/2}$[f]	192112.5[i]	0.2	0.12	0.3	4
$4p^2 5p\ (^1D)\ ^2P_{1/2}$	194917.3	0.2	0.14	0.4	3
$4p^2 5p\ (^1D)\ ^2P_{3/2}$	196961.6	0.2	0.2	0.4	4
$4p^2 5p\ (^1S)\ ^2P_{1/2}$	209741.7	0.6	0.3	0.6	2
$4p^2 5p\ (^1S)\ ^2P_{3/2}$	210121.1	0.3	0.3	0.6	2
$4p^2 6s\ (^3P)\ ^4P_{1/2}$	210591.3[d]	1.3	1.1		3
$4p^2 5d\ (^3P)\ ^4F_{3/2}$	211697.1[d]	1.2	1.2		3
$4p^2 5d\ (^3P)\ ^4F_{5/2}$	212438.9[d]	1.3	1.2		3
$4p^2 6s\ (^3P)\ ^4P_{3/2}$	213007.3[d]	1.2	1		4
$4p^2 6s\ (^3P)\ ^2P_{1/2}$	213811.0[d]	3	3		1
$4p^2 5d\ (^3P)\ ^4F_{7/2}$	214258.0[d]	2	2		1
$4p^2 5d\ (^3P)\ ^4D_{3/2}$	214868.8[d]	1.2	0.9		5
$4p^2 5d\ (^3P)\ ^4P_{5/2}$	215086.3[d]	1.4	1.2		3
$4p^2 5d\ (^3P)\ ^4D_{1/2}$	215100.0[d]	2	1.3		2
$4p^2 6s\ (^3P)\ ^4P_{5/2}$	215915.0[d]	0.5	0.5		1
$4p^2 5d\ (^3P)\ ^2P_{3/2}$	216384.9[d]	1.1	0.9		5
$4p^2 5d\ (^3P)\ ^4F_{9/2}$[*]	216525.5	0.104	0.15		1
$4p^2 5d\ (^3P)\ ^2F_{5/2}$	216880.3[d]	1.5	1.2		3
$4p^2 5d\ (^3P)\ ^4D_{7/2}$	217161.7[d]	2	2		1
$4p^2 6s\ (^3P)\ ^2P_{3/2}$	217515.1[d]	1.1	1		4
$4p^2 4f\ (^3P)\ ^4G_{5/2}$	217891.8	0.2	0.3		6
$4p^2 4f\ (^3P)\ ^4G_{7/2}$	217983.0	0.12	0.2		6

$4p^25d\,(^3P)\ ^4D_{5/2}$	218426.3[d]	2	1.3		3
$4p^25d\,(^3P)\ ^4P_{3/2}$	218911.9[d]	1.2	1.3		3
$4p^25d\,(^3P)\ ^4P_{1/2}$	219192.0[d]	2	2		1
$4p^24f\,(^3P)\ ^4D_{7/2}$	219469.7	0.3	0.3		4
$4p^24f\,(^3P)\ ^2D_{5/2}$	219712.8	0.4	0.3		3
$4p^25d\,(^3P)\ ^2P_{1/2}$	219808.4[d]	1	1		4
$4p^25d\,(^3P)\ ^2F_{7/2}$	220337.7[d]	2.1	2.1		1
$4p^24f\,(^3P)\ ^4G_{9/2}$	220531.8	0.2	0.3		2
$4p^24f\,(^3P)\ ^4D_{5/2}$	220675.2	0.3	0.2		5
$4p^24f\,(^3P)\ ^2G_{7/2}$	220698.3	0.2	0.2		5
$4p^24f\,(^3P)\ ^2D_{3/2}$	220898.9	0.2	0.2		9
$4p^24f\,(^3P)\ ^4D_{3/2}$	221435.6	0.14	0.2		7
$4p^25d\,(^3P)\ ^2D_{3/2}$	221974.3[d]	1.2	1.1		3
$4p^25d\,(^3P)\ ^2D_{5/2}$	222017.7[d]	1.2	1.2		3
$4p^24f\,(^3P)\ ^4G_{11/2}$	222068.4	0.3	0.3		1
$4p^24f\,(^3P)\ ^4D_{1/2}$	222354.6	0.2	0.3		3
$4p^24f\,(^3P)\ ^4F_{9/2}$	223150.3	0.13	0.2		3
$4p^24f\,(^3P)\ ^4F_{3/2}$	223277.5	0.2	0.3		3
$4p^24f\,(^3P)\ ^4F_{5/2}$	223871.5	0.2	0.2		5
$4p^24f\,(^3P)\ ^4F_{7/2}$	223893.6	0.3	0.2		6
$4p^24f\,(^3P)\ ^2G_{9/2}$	224041.3	0.2	0.3		3
$4p^24f\,(^3P)\ ^2F_{5/2}$	225243.0	0.2	0.2		5
$4p^24f\,(^3P)\ ^2F_{7/2}$	225652.7	0.2	0.2		4
$4p^26s\,(^1D)\ ^2D_{5/2}$	226677.5[d]	1.4	1.2		3
$4p^26s\,(^1D)\ ^2D_{3/2}$	226807.7[d]	1.4	1.3		3
$4p^25d\,(^1D)\ ^2G_{7/2}$	227864.6[d]	3.2	3.2		1
$4p^25d\,(^1D)\ ^2G_{9/2}$*	228384.8	0.102	0.14	–	1
$4p^25d\,(^1D)\ ^2F_{7/2}$	229133.0[d]	2	2		1
$4p^25d\,(^1D)\ ^2F_{5/2}$	229168.9[d]	1.3	1.3		3
$4p^25d\,(^1D)\ ^2D_{3/2}$	230184.6[d]	1.2	1.1		4
$4p^25d\,(^1D)\ ^2P_{1/2}$	230505.0[d]	2	2		2
$4p^25d\,(^1D)\ ^2D_{5/2}$	230894.3[d]	1.3	1.3		3
$4p^25d\,(^1D)\ ^2P_{3/2}$	231541.4[d]	1.4	1.3		3
$4p^25d\,(^1D)\ ^2S_{1/2}$	232610.7[d]	1.2	1.2		4
$4p^24f\,(^1D)\ ^2G_{9/2}$	233546.9	0.2	0.2		4
$4p^24f\,(^1D)\ ^2F_{7/2}$	233824.7	0.13	0.2		5
$4p^24f\,(^1D)\ ^2G_{7/2}$	233917.3	0.09	0.2		5
$4p^24f\,(^1D)\ ^2F_{5/2}$	234413.6	0.08	0.2		8
$4p^24f\,(^1D)\ ^2D_{3/2}$	235910.2	0.3	0.3		4
$4p^24f\,(^1D)\ ^2D_{5/2}$	236126.2	0.14	0.2		4
$4p^24f\,(^1D)\ ^2H_{9/2}$	236290.8	0.2	0.3		3
$4p^24f\,(^1D)\ ^2H_{11/2}$	236322.6	0.2	0.3		2
$4p^27s\,(^3P)\ ^4P_{1/2}$	237608.0[d]	2	2		2
$4p^24f\,(^1D)\ ^2P_{1/2}$	237996.8	0.1	0.4		4
$4p^26d\,(^3P)\ ^4F_{3/2}$	238425.1[d]	2	1.4		3
$4p^24f\,(^1D)\ ^2P_{3/2}$	238438.9	0.4	0.3		3

$4p^26d\,(^3P)\ ^4F_{5/2}$	238829.0[d]	2	2	2
$4p^27s\,(^3P)\ ^4P_{3/2}$	240114.0[d]	2	2	2
$4p^27s\,(^3P)\ ^2P_{1/2}$	240447.0[d]	2	2	2
$4p^26d\,(^3P)\ ^4F_{7/2}$	240998.7[d]	2.5	2.5	1
$4p^26d\,(^3P)\ ^4P_{5/2}$	241035.0[d]	2	2	2
$4p^26d\,(^3P)\ ^2P_{3/2}$	241206.0[d]	2	1.5	3
$4p^26d\,(^3P)\ ^4D_{3/2}$	241954.5[d]	2	1.3	4
$4p^26d\,(^3P)\ ^2F_{5/2}$	242178.6[d]	2.6	2.6	1
$4p^27s\,(^3P)\ ^4P_{5/2}$	243028.0[d]	2	2	2
$4p^26d\,(^3P)\ ^4D_{7/2}$	243792.0[d]	3	3	1
$4p^27s\,(^3P)\ ^2P_{3/2}$	244186.6[d]	1.4	1.4	3
$4p^26d\,(^3P)\ ^4D_{5/2}$	244205.0[d]	2	2	2
$4p^26d\,(^3P)\ ^4P_{3/2}$	244342.0[d]	3	3	1
$4p^26d\,(^3P)\ ^4P_{1/2}$	244439.6[d]	3	3	1
$4p^25d\,(^1S)\ ^2D_{5/2}$	244940.0[d]	3	2	2
$4p^26d\,(^3P)\ ^2F_{7/2}$	245342.0[d]	3	3	1
$4p^26s\,(^1S)\ ^2S_{1/2}$	245552.0[d]	2	2	2
$4p^26d\,(^3P)\ ^2D_{5/2}$	246841.0[d]	2	1.5	3
$4p^25d\,(^1S)\ ^2D_{3/2}$	247102.0[d]	3	2	2
$4p^27s\,(^1D)\ ^2D_{5/2}$	253717.0[d]	2	2	2
$4p^27s\,(^1D)\ ^2D_{3/2}$	253753.0[d]	3	2	3
$4p^26d\,(^1D)\ ^2F_{7/2}$	254969.7[d]	2.8	2.9	1
$4p^26d\,(^1D)\ ^2G_{7/2}$	255429.7[d]	2.9	2.9	1
$4p^26d\,(^1D)\ ^2D_{3/2}$	255875.0[d]	2	2	2
$4p^26d\,(^1D)\ ^2D_{5/2}$	255920.0[d]	2	2	2
$4p^26d\,(^1D)\ ^2P_{3/2}$	256337.4[d]	2.6	2.6	1

[x] Represent designations of the levels.
[a] Uncertainty D_1 is close to the minimum estimated dispersion relative to any other term.
[b] D_2 is the uncertainty of the level value relative to the ground level
[c] D_3 is the estimated uncertainty relative to the lowest fixed level in the isolated level system (here, "isolated" means "isolated from the ground level"). All uncertainties were determined by the LOPT code [12].
[y] No. of observed transitions corresponding to each level.
[d] Levels established by Jabeen and Tauheed [6].
[f] Designation changed.
[g] Levels established by Rao and Krishnamurty [1].
[h] Levels established by Bhupala Rao [3].
[i] Levels established in earlier work which are compiled in NIST[2].
[*] New levels of the even parity configurations $4p^2nd$ (for J=9/2) have also been established in the present work.

Table 3.3: Observed and least squares fitted (LSF) energy levels of Br III in cm^{-1}.

J	E(obs)	E(LSF)	diff.[a]	LS-composition
Odd configurations				
1/2	27198.5	27200.0	-1.5	$99\%\ 4s^24p^3\,^2P$
	171281.7	171312.0	-30.3	$65\%\ 4s^24p^25p(^3P)^2S + 19\% 4s^24p^25p(^3P)^4D + 7\% 4s^24p^25p(^3P)^4P + 5\% 4s^24p^25p(^3P)^2P$
	173172.9	173182.0	-9.1	$75\%\ 4s^24p^25p(^3P)^4D + 23\% 4s^24p^25p(^3P)^2S$
	177486.4	177428.0	58.4	$90\%\ 4s^24p^25p(^3P)^4P + 5\% 4s^24p^25p(^3P)^2S$
	183386.7	183690.0	-303.3	$84\%\ 4s^24p^25p(^3P)^2P + 5\% 4s^24p^25p(^3P)^2S$
	194917.3	195121.0	-203.7	$92\%\ 4s^24p^25p(^1D)^2P + 6\% 4s^24p^25p(^3P)^2P$
	209741.7	209722.0	19.7	$93\%\ 4s^24p^25p(^1S)^2P$
	-	219664.0	-	$100\%\ 4s4p^34d((^4S)^5S)^6D$
	222354.6	222388.0	-33.4	$95\%\ 4s^24p^24f(^3P)^4D$
	-	226091.0	-	$57\%\ 4s^24p^26p(^3P)^4D + 20\% 4s^24p^26p(^3P)^2S + 11\%\ 4s^24p^26p(^3P)^4P + 8\% 4s^24p^26p(^3P)^2P$
	-	227891.0	-	$52\%\ 4s^24p^26p(^3P)^2S + 36\% 4s^24p^26p(^3P)^4D + 10\% 4s^24p^26p(^3P)^4P$
	-	229724.0	-	$74\%\ 4s^24p^26p(^3P)^4P + 12\% 4s^24p^26p\,(^3P)^2P + 12\%\ 4s^24p^26p\,(^3P)^2S$
	-	233207.0	-	$76\%\ 4s^24p^26p(^3P)^2P + 14\% 4s^24p^26p\,(^3P)^2S + 4\% 4s^24p^26p\,(^3P)^4D$
	237996.8	238063.0	-66.2	$95\%\ 4s^24p^24f(^1D)^2P$
	-	239882.0	-	$78\%\ 4s4p^34d((^4S)^5S)^4D + 17\% 4s4p^34d\,((^2D)^3D)^4D + 4\%\ 4s4p^34d((2P)^3P)^4D$
	-	244724.0	-	$97\%\ 4s^24p^26p(^1D)^2P$
	-	249145.0	-	$95\%\ 4s^24p^25f(^3P)^4D$
	-	261160.0	-	$60\%\ 4s^24p^26p(^1S)^2P + 36\%\ 4s^24p^25f(^1D)^2P$
	-	263067.0	-	$60\%\ 4s^24p^25f(^1D)^2P + 36\%\ 4s^24p^26p(^1S)^2P$
	-	265414.0	-	$78\%\ 4s4p^34d((^2D)^3D)^2S + 6\% 4s4p^35s((^2D)^3D)^4D + 6\% 4s4p^34d((2D)^1D)^2S + 4\% 4s4p^34d((^2D)^3D)^4D$
	-	265620.0	-	$48\% 4s4p^35s((2D)^3D)^4D + 25\% 4s4p^34d((^2D)^3D)^4D + 12\% 4s4p^34d((2D)^3D)^2S + 9\% 4s4p^34d((^2P)^3P)^4D$
	-	269447.0	-	$41\% 4s4p^35s((2D)^3D)^4D + 40\% 4s4p^34d((^2D)^3D)^4D + 7\% 4s4p^34d((^2P)^3P)^4D$
	-	272387.0	-	$77\%\ 4s4p^34d((^2D)^3D)^4P + 13\% 4s4p^35s((^2P)^3P)^4P + 7\% 4s4p^34d((^2P)^3P)^4P$
	-	273028.0	-	$75\% 4s4p^34d((^2D)^3D)^2P + 9\% 4s4p^34d((^2P)^3P)^4P + 4\% 4s4p^35s((^2P)^3P)^2P$
	-	275397.0	-	$79\%\ 4s4p^34d((^2P)^3P)^4P + 9\% 4s4p^34d((^2D)^3D)^2P + 7\%\ 4s4p^34d((^2D)^3D)^4P$
3/2	0.0	0.0	0.0	$97\%\ 4s^24p^3\,^4S$
	15248.8	15247.0	1.8	$90\%\ 4s^24p^3\,^2D + 8\% 4s^24p^3\,^2P$
	28672.4	28671.0	1.4	$90\%\ 4s^24p^3\,^2P + 8\% 4s^24p^3\,^2D$
	173830.9	173734.0	96.9	$82\%\ 4s^24p^25p(^3P)^4D + 11\% 4s^24p^25p(^3P)^4P$
	176661.7	176712.0	-50.3	$44\%\ 4s^24p^25p(^3P)^4P + 19\% 4s^24p^25p(^3P)^4S + 15\% 4s^24p^25p(^3P)^2D + 14\% 4s^24p^25p(^3P)^4D$
	178121.3	178417.0	-295.7	$63\%\ 4s^24p^25p(^3P)^2D + 15\% 4s^24p^25p(^3P)^4S + 11\% 4s^24p^25p(^1D)^2D + 10\% 4s^24p^25p(^3P)^4P$
	180245.0	180356.0	-111.0	$61\%\ 4s^24p^25p(^3P)^4S + 31\% 4s^24p^25p(^3P)^4P$
	183751.4	183500.0	251.4	$77\%\ 4s^24p^25p(^3P)^2P + 12\% 4s^24p^25p(^1D)^2P + 6\% 4s^24p^25p(^1D)^2D$
	191904.2	191779.0	125.2	$70\%\ 4s^24p^25p(^1D)^2D + 13\%\ 4s^24p^25p(^1D)^2P + 12\% 4s^24p^25p(^3P)^2D$
	196961.6	196800.0	161.6	$68\%\ 4s^24p^25p(^1D)^2P + 19\% 4s^24p^25p(^3P)^2P$

				+7%$4s^24p^25p(^1D)^2D$
	210121.1	210053.0	68.1	94% $4s^24p^25p(^1S)^2P$
	-	219695.0	-	99% $4s4p^34d((^4S)^5S)^6D$
	220898.9	220567.0	331.9	36% $4s^24p^24f(^3P)^4D$+ 34%$4s^24p^24f(^3P)^4F$
				+28%$4s^24p^24f(^3P)^2D$
	221435.6[b]	222482.0	-	49% $4s^24p^24f(^3P)^4D$+ 44%$4s^24p^24f(^3P)^2D$
	223277.4	223574.0	-296.6	61% $4s^24p^24f(^3P)^4F$+ 25%$4s^24p^24f(^3P)^2D$
				+10%$4s^24p^24f(^3P)^4D$
	-	226804.0	-	47%$4s^24p^26p(^3P)^4D$ + 26%$4s^24p^26p(^3P)^4P$
				+13%$4s^24p^26p(^3P)^4S$+ 10%$4s^24p^26p(^3P)^2D$
	-	228595.0	-	40% $4s^24p^26p(^3P)^4D$+ 39% $4s^24p^26p(^3P)^4S$
				+10%$4s^24p^26p(^3P)^4P$ +5%$4s4p^35s((^4S)^5S)^4S$
	-	229869.0	-	78%$4s^24p^26p(^3P)^2D$ +7%$4s^24p^26p(^3P)^4S$
				+6%$4s^24p^26p(^3P)^4D$ +5%$4s^24p^26p(^3P)^2P$
	-	231366.0	-	58% $4s^24p^26p(^3P)^4P$+ 25%$4s^24p^26p(^3P)^4S$
				+6%$4s4p^35s((^4S)^5S)^4S$+4%$4s^24p^26p(^3P)^2D$
	-	233583.0	-	81% $4s^24p^26p(^3P)^2P$+7%$4s^24p^26p(^1D)^2D$
	235910.2	235918.0	-7.8	95%$4s^24p^24f(^1D)^2D$
	238438.9	238075.0	363.9	95% $4s^24p^24f(^1D)^2P$
	-	238341.0	-	84% $4s4p^35s((^4S)^5S)^4S$ + 13%$4s^24p^26p(^3P)^4S$
	-	239755.0	-	77% $4s4p^34d((^4S)^5S)^4D$ + 17%$4s4p^34d((^2D)^3D)^4D$
				+4%$4s4p^34d((^2P)^3P)^4D$
	-	243153.0	-	84%$4s^24p^26p(^1D)^2D$+7%$4s^24p^26p(^1D)^2P$
	-	245222.0	-	85% $4s^24p^26p(^1D)^2P$+ 5%$4s^24p^26p(^1D)^2D$
				+5%$4s^24p^26p(^3P)^2P$
	-	246610.0	-	57%$4s^24p^25f(^3P)^4F$+21%$4s^24p^25f(^3P)^4D$
				+19%$4s^24p^25f(^3P)^2D$
	-	249169.0	-	68% $4s^24p^25f(^3P)^4D$+ 21%$4s^24p^25f(^3P)^2D$
				+6%$4s^24p^25f(^3P)^4F$
	-	249482.0	-	57% $4s^24p^25f(^3P)^2D$+ 32%$4s^24p^25f(^3P)^4F$
				+6%$4s^24p^25f(^3P)^4D$
	-	254865.0	-	78%$4s4p^34d((^2D)^3D)^4F$ + 19%$4s4p^34d((^2P)^3P)^4F$
	-	261252.0	-	50% $4s^24p^26p(^1S)^2P$+ 38%$4s^24p^25f(^1D)^2P$
				+8%$4s^24p^25f(^1D)^2D$
	-	261379.0	-	88%$4s^24p^25f(^1D)^2D$+5%$4s^24p^26p(^1S)^2P$
	-	263149.0	-	54%$4s^24p^25f(^1D)^2P$+ 42% $4s^24p^26p(^1S)^2P$
	-	265798.0	-	61%$4s4p^35s((^2D)^3D)^4D$ + 23%$4s4p^34d((^2D)^3D)^4D$
				+ 8%$4s4p^34d((^2P)^3P)^4D$
	-	269543.0	-	40%$4s4p^34d((^2D)^3D)^4D$+31%$4s4p^35s((^2D)^3D)^4D$
				+7%$4s4p^34d((^4S)^5S)^4D$+6%$4s4p^34d((^2P)^3P)^4D$
	-	271476.0	-	38%$4s4p^34d((^2D)^3D)^2P$ +24%$4s4p^35s((^2D)^3D)^2D$
				+7%$4s4p^34d((^2D)^3D)^4D$ +7%$4s4p^34d((^2P)^3P)^2D$
	-	272066.0	-	36%$4s4p^34d((^2D)^3D)^4P$ +29%$4s4p^35s((^2D)^3D)^2D$
				+8%$4s4p^34d((^2D)^3D)^2P$ +7%$4s4p^34d((^2P)^3P)^2D$
	-	273089.0	-	46%$4s4p^34d((^2D)^3D)^4P$ +21%$4s4p^34d((^2D)^3D)^2P$
				+14%$4s4p^35s((^2D)^3D)^2D$ +6%$4s4p^35s((^2P)^3P)^4P$
	-	274961.0	-	78% $4s4p^34d((^2P)^3P)^4P$+11%$4s4p^34d((^2D)^3D)^2P$
	-	276161.0	-	68% $4s4p^34d((^2P)^3P)^4F$+14%$4s\ 4p^34d((^2D)^3D)^4F$
				+6%$4s4p^35s((^2D)^3D)^2D$ +4%$4s4p^34d((^2P)^3P)^2D$
	-	277491.0	-	32%$4s4p^34d((^2P)^3P)^2D$ +28%$4s4p^34d((^2D)^3D)^2D$
				+20%$4s4p^35s((^2D)^3D)^2D$ +9%$4s4p^34d((^2P)^3P)^4F$
5/2	16306.8	16308.0	-1.2	98% $4s^24p^3\ ^2D$
	175901.1	175796.0	105.1	89% $4s^24p^25p(^3P)^4D$ +9%$4s^24p^25p(^3P)^4P$
	179364.0	178837.0	527.0	58% $4s^24p^25p(^3P)^4P$ +20%$4s^24p^25p(^3P)^2D$
				+ 11%$4s^24p^25p(^1D)^2D$ +8%$4s^24p^25p(^3P)^4D$
	182204.6	182328.0	-123.4	60% $4s^24p^25p(^3P)^2D$ + 30%$4s^24p^25p(^3P)^4P$
				+4%$4s^24p^25p(^1D)^2F$
	190913.1	190673.0	240.1	63% $4s^24p^25p(^1D)^2F$ +34%$4s^24p^25p(^1D)^2D$
	192112.5	192043.0	69.5	49%$4s^24p^25p(^1D)^2D$ + 30%$4s^24p^25p(^1D)^2F$

				$+18\%4s^24p^25p(^3P)^2D$
	217891.8	217692.0	199.7	$62\%4s^24p^24f(^3P)^4G + 14\%4s^24p^24f(^3P)^2D$
				$+10\%4s^24p^24f(^3P)^4F +5\%4s^24p^24f(^3P)^4D$
	219712.8	219577.0	135.8	$40\%4s^24p^24f(^3P)^2D +27\%4s^24p^24f(^3P)^4G$
				$+19\%4s^24p^24f(^3P)^4D + 8\%4s4p^34d((^4S)^5S)^6D$
	-	219762.0	-	$91\% 4s4p^34d((^4S)^5S)^6D + 5\%4s^24p^24f(^3P)^2D$
	220675.2	220710.0	-34.8	$51\% 4s^24p^24f(^3P)^4D + 28\%4s^24p^24f(^3P)^2D$
				$+10\%4s^24p^24f(^3P)^4F + 8\%4s^24p^24f(^3P)^2F$
	223871.5	223591.0	280.5	$70\%4s^24p^24f(3P)^4F + 20\%4s^24p^24f(^3P)^4D$
	225243.0	225173.0	70.0	$82\%4s^24p^24f(^3P)^2F + 8\%4s^24p^24f(^3P)^2D$
	-	227707.0	-	$99\%4s4p^35s((^4S)^5S)^6S$
	-	228883.0	-	$74\%4s^24p^26p(^3P)^4D + 18\%4s^24p^26p(^3P)^4P$
				$+6\%4s^24p^26p(^3P)^2D$
	-	231584.0	-	$55\% 4s^24p^26p(^3P)4P+23\%4s^24p^26p(^3P)^4D$
				$+15\%4s^24p^26p(^3P)^2D+ 5\%4s^24p^26p(^1D)^2D$
	-	233077.0	-	$71\% 4s^24p^26p(^3P)^2D +22\%4s^24p^26p(^3P)^4P$
	234413.6	233912.0	501.6	$88\% 4s^24p^24f(^1D)^2F$
	236126.2	236174.0	-47.8	$94\% 4s^24p^24f(^1D)^2D$
	-	239673.0	-	$76\% 4s4p^34d((^4S)^5S)^4D +18\%4s4p^34d((^2D)^3D)^4D$
	-	242943.0	-	$89\% 4s^24p^26p(^1D)^2D + 5\%4s^24p^26p(^1D)^2F$
	-	243456.0	-	$89\% 4s^24p^26p(^1D)^2F + 5\%4s^24p^26p(^3P)^2D$
				$+4\%4s^24p^26p(^1D)^2D$
	-	243875.0	-	$58\% 4s^24p^25f(^3P)^4G + 14\%4s^24p^25f(^3P)^4F$
				$+11\%4s^24p^25f(^3P)^2D + 6\%4s^24p^25f(^3P)^2F$
	-	246074.0	-	$38\%4s^24p^25f(^3P)^2D + 29\%4s^24p^25f(^3P)^4G$
				$+19\%4s^24p^25f(^3P)^4D +9\%4s^24p^25f(^3P)^4F$
	-	246991.0	-	$29\%4s^24p^25f(^3P)^4D +29\%4s^24p^25f(^3P)^2D$
				$+20\%4s^24p^25f(^3P)^4F+20\%4s^24p^25f(^3P)^2F$
	-	249334.0	-	$49\% 4s^24p^25f(^3P)^4F +41\%4s^24p^25f(^3P)^4D$
	-	250283.0	-	$69\% 4s^24p^25f(^3P)^2F + 17\%4s^24p^25f(^3P)^2D$
	-	254294.0	-	$91\% 4s^24p^24f(^1S)^2F$
	-	255393.0	-	$78\% 4s4p^34d((^2D)^3D)^4F +18\%4s4p^34d((^2P)^3P)^4F$
	-	260791.0	-	$89\% 4s^24p^25f(^1D)^2F$
	-	261547.0	-	$93\% 4s^24p^25f(^1D)^2D$
	-	262569.0	-	$89\% 4s4p^34d((^2D)^3D)^4G +6\%4s^24p^25f(^3P)^4G$
	-	266185.0	-	$70\% 4s4p^35s((^2D)^3D)^4D + 16\%4s4p^34d((^2D)^3D)^4D$
				$+6\%4s4p^34d((^2P)^3P)^4D$
	-	270058.0	-	$41\%4s4p^34d((^2D)^3D)^4D +21\%4s4p^35s((^2D)^3D)^4D$
				$+12\%4s4p^34d((^2P)^3P)^4P +8\%4s4p^34d((^4S)^5S)^4D$
	-	270889.0	-	$39\%4s4p^34d((^2D)^3D)^4P +18\%4s4p^35s((^2D)^3D)^2D$
				$+12\%4s4p^34d((^2P)^3P)^2D +11\%4s4p^34d((^2P)^3P)^4P$
	-	271542.0	-	$22\%4s4p^35s((^2D)^3D)^2D +18\%4s4p^34d((^2P)^3P)^2D$
				$+16\%4s4p^34d((^2D)^3D)^4P + 12\%4s4p^34d((^2D)^3D)^2D$
	-	275667.0	-	$36\%4s4p^35s((^2D)^3D)^2D +25\%4s4p^34d((^2P)^3P)^4F$
				$+13\% 4s4p^34d((^2P)^3P)^2D + 12\%4s4p^34d((^2D)^3D)^2D$
	-	276228.0	-	$50\% 4s4p^34d((^2P)^3P)^4F+16\%4s4p^35s((^2D)^3D)^2D$
				$+11\%4s4p^34d((^2D)^3D)^4F +7\%4s4p^34d((^2D)^3D)^2D$
	-	276547.0	-	$55\% 4s4p^34d((^2P)^3P)^4P +19\%4s4p^34d((^2D)^3D)^4P$
				$+14\%4s4p^35s((^2P)^3P)^4P$
	-	279493.0	-	$93\%4s^24p^25f(^1S)^2F$
7/2	178313.8	178267.0	46.8	$95\% 4s^24p^25p(^3P)^4D$
	191045.4	191618.0	-572.6	$96\% 4s^24p^25p(^1D)^2F$
	217983.0	218019.0	-36.0	$34\% 4s^24p^24f(^3P)^4D + 32\%4s^24p^24f(^3P)^4G$
				$+18\%4s^24p^24f(^3P)^4F +11\%4s^24p^24f(^3P)^2G$
	219469.7	219610.0	-140.3	$39\% 4s^24p^24f(^3P)^4D + 36\%4s^24p^24f(^3P)^4G$
				$+19\%4s4p^34d((^4S)^5S)^6D$
	-	219878.0	-	$80\%4s4p^34d((^4S)^5S)^6D +10\%4s^24p^24f(^3P)^4G$
				$+8\%4s^24p^24f(^3P)^4D$
	220698.3	221040.0	-341.7	$76\% 4s^24p^24f(^3P)^2G +11\%4s^24p^24f(^3P)^4G$

				+6% $4s^24p^24f(^3P)^2F$
	223893.6	223786.0	107.6	76% $4s^24p^24f(^3P)^4F$ +9% $4s^24p^24f(^3P)^4D$ +6% $4s^24p^24f(^3P)^4G$
	225652.7	225493.0	159.7	84% $4s^24p^24f(^3P)^2F$ +7% $4s^24p^24f(^1D)^2G$
	-	231354.0	-	94% $4s^24p^26p(^3P)^4D$
	233824.7	233819.0	5.7	60% $4s^24p^24f(^1D)^2F$ + 31% $4s^24p^24f(^1D)^2G$
	233917.3	234104.0	-186.7	57% $4s^24p^24f(^1D)^2G$ + 30% $4s^24p^24f(^1D)^2F$ +6% $4s^24p^24f(^3P)^2F$
	-	239842.0	-	76% $4s4p^34d((^4S)^5S)4D$ +19% $4s4p^34d((^2D)^3D)^4D$
	-	243626.0	-	95% $4s^24p^26p(^1D)^2F$
	-	244173.0	-	32% $4s^24p^25f(^3P)^4G$ + 24% $4s^24p^25f(^3P)^4F$ +23% $4s^24p^25f(^3P)^4D$ + 14% $4s^24p^25f(^3P)^2G$
	-	246115.0	-	45% $4s^24p^25f(^3P)^4D$ +43% $4s^24p^25f(^3P)^4G$ +5% $4s^24p^25f(^3P)^2F$
	-	247016.0	-	72% $4s^24p^25f(^3P)^2G$ +9% $4s^24p^25f(^3P)^2F$ +7% $4s^24p^25f(^3P)^4D$ + 6% $4s^24p^25f(^3P)^4G$
	-	249322.0	-	65% $4s^24p^25f(^3P)^4F$ +17% $4s^24p^25f(^3P)^4D$ +9% $4s^24p^25f(^3P)^4G$
	-	250531.0	-	76% $4s^24p^25f(^3P)2F$ + 9% $4s^24p^25f(^3P)^2G$ +5% $4s^24p^25f(^1D)^2G$
	-	254236.0	-	91% $4s^24p^24f(^1S)^2F$
	-	256123.0	-	79% $4s4p^34d((^2D)^3D)^4F$ +16% $4s4p^34d((^2P)^3P)^4F$
	-	260455.0	-	87% $4s^24p^25f(^1D)^2G$
	-	260762.0	-	90% $4s^24p^25f(^1D)^2F$
	-	262765.0	-	86% $4s4p^34d((^2D)^3D)^4G$ +7% $4s^24p^25f(^3P)^4G$
	-	267027.0	-	82% $4s4p^35s((^2D)^3D)^4D$ +12% $4s4p^34d((^2D)^3D)^4D$
	-	269528.0	-	92% $4s4p^34d((^2D)^3D)^2G$
	-	271291.0	-	64% $4s4p^34d((^2D)^3D)^4D$ +15% $4s4p^35s((^2D)^3D)^4D$ +14% $4s4p^34d((^4S)^5S)^4D$
	-	275725.0	-	78% $4s4p^34d((^2P)^3P)^4F$ +12% $4s4p^34d((^2D)^3D)^4F$
	-	279348.0	-	91% $4s^24p^25f(^1S)^2F$
9/2	-	219854.0	-	79% $4s4p^34d((^4S)^5S)^6D$ +13% $4s^24p^24f(^3P)^4G$ +5% $4s^24p^24f(^3P)^4F$
	220531.7	220198.0	333.7	61% $4s^24p^24f(^3P)^4G$ +20% $4s4p^34d((^4S)^5S)^6D$ + 11% $4s^24p^24f(^3P)^4F$ +6% $4s^24p^24f(^3P)^2G$
	223150.3	223275.0	-124.7	37% $4s^24p^24f(^3P)^4F$ +35% $4s^24p^24f(^3P)^2G$ +21% $4s^24p^24f(^3P)^4G$
	224041.2	224390.0	-348.8	54% $4s^24p^24f(^3P)^2G$ + 41% $4s^24p^24f(^3P)^4F$
	233546.8	233560.0	-13.2	93% $4s^24p^24f(^1D)^2G$
	236290.8	236609.0	-318.2	96% $4s^24p^24f(^1D)^2H$
	-	246125.0	-	61% $4s^24p^25f(^3P)^4G$ + 25% $4s^24p^25f(^3P)^4F$ +8% $4s^24p^25f(^3P)^2G$ +4% $4s4p^34d((2D)^3D)^4G$
	-	249002.0	-	49% $4s^24p^25f(^3P)^4F$+29% $4s^24p^25f(^3P)^4G$ + 11% $4s^24p^25f(^3P)^2G$
	-	249997.0	-	76% $4s^24p^25f(^3P)^2G$ + 19% $4s^24p^25f(^3P)^4F$
	-	257088.0	-	81% $4s4p^34d((^2D)^3D)^4F$ + 14% $4s4p^34d((^2P)^3P)^4F$
	-	260203.0	-	89% $4s^24p^25f(^1D)^2G$
	-	261689.0	-	88% $4s^24p^25f(^1D)^2H$ + 8% $4s4p^34d((^2D)^3D)^4G$
	-	263146.0	-	77% $4s4p^34d((^2D)^3D)^4G$ + 9% $4s^24p^25f(^3P)^4G$ +7% $4s^24p^25f(^1D)^2H$
	-	269675.0	-	89% $4s4p^34d((^2D)^3D)^2G$ +4% $4s4p^34d((^2P)^3P)^4F$
	-	275535.0	-	78% $4s4p^34d((^2P)^3P)^4F$ + 10% $4s4p^34d((^2D)^3D)^4F$ +6% $4s4p^34d((^2D)^3D)^2G$
11/2	222068.4	222261.0	-192.6	94% $4s^24p^24f(^3P)^4G$
	236322.6	236545.0	-222.4	97% $4s^24p^24f(^1D)^2H$
	-	248402.0	-	88% $4s^24p^25f(^3P)^4G$ +8% $4s4p^34d((^2D)^3D)^4G$
	-	261482.0	-	86% $4s^24p^25f(^1D)^2H$ +13% $4s4p^34d((^2D)^3D)^4G$
	-	263741.0	-	76% $4s4p^34d((^2D)^3D)^4G$ +11% $4s^24p^25f(^3P)^4G$ +11% $4s^24p^25f(^1D)^2H$

Even configurations

1/2	105372.1	105446.0	-73.9	85% $4s4p^4(^3P)^4P$ +13% $4s^24p^24d(^3P)^4P$
	137520.0	137226.0	294.0	63% $4s^24p^24d(^3P)^2P$ +23% $4s4p^4(^3P)^2P$ +4% $4s^24p^24d(^1D)^2P$
	145408.6	145333.0	75.6	88% $4s^24p^25s(^3P)^4P$ +4% $4s^24p^25s(^3P)^2P$
	146157.3	146055.0	102.3	90% $4s^24p^24d(^3P)^4D$ +4% $4s^24p^25s(^3P)^4P$
	147842.5	148049.0	-206.5	60% $4s4p^4(^1S)^2S$ +32% $4s^24p^24d(^1D)^2S$
	151054.4	150979.0	75.4	89% $4s^24p^25s(^3P)^2P$ +5% $4s^24p^25s(^3P)^4P$
	164338.9	164392.0	-53.1	82% $4s^24p^24d(^3P)^4P$ +11% $4s4p^4(^3P)^4P$
	173116.8	173518.0	-401.2	76% $4s^24p^24d(^1D)^2P$ +18% $4s4p^4(^3P)^2P$
	177409.2	177178.0	231.2	79% $4s^24p^25s(^1S)^2S$ +6% $4s^24p^24d(^1D)^2S$ +6% $4s4p^4(^1S)^2S$
	180987.7	180914.0	73.7	45% $4s4p^4(^3P)^2P$ +27% $4s^24p^24d(^3P)^2P$ +11% $4s^24p^24d(^1D)^2P$ +4% $4s^24p^25d(^3P)^2P$
	188445.8	187985.0	460.8	51% $4s^24p^24d(^1D)^2S$ + 25% $4s4p^4(^1S)^2S$ + 11% $4s^24p^25s(^1S)^2S$
	210591.3	210662.0	-70.7	82% $4s^24p^26s(^3P)^4P$ + 15% $4s^24p^26s(^3P)^2P$
	213811.0	213781.0	30.0	80% $4s^24p^26s(^3P)^2P$ + 15% $4s^24p^26s(^3P)^4P$
	215100.0	215018.0	82.0	86% $4s^24p^25d(^3P)^4D$ + 6% $4s^24p^25d(^3P)^2P$
	219192.0	219081.0	111.0	90% $4s^24p^25d(^3P)^4P$
	219808.4	219866.0	-57.6	84% $4s^24p^25d(^3P)^2P$ + 8% $4s^24p^25d(^3P)^4D$
	230505.0	230223.0	282.0	95% $4s^24p^25d(^1D)^2P$
	232610.7	232811.0	-200.3	91% $4s^24p^25d(^1D)^2S$
	237608.0	237954.0	-344.0	74% $4s^24p^27s(^3P)^4P$ + 23% $4s^24p^27s(^3P)^2P$
	240447.0	240598.0	-151.0	72% $4s^24p^27s(^3P)^2P$ + 23% $4s^24p^27s(^3P)^4P$
	-	241036.0	-	78% $4s^24p^26d(^3P)^4D$ + 11% $4s^24p^26d(^3P)^2P$ + 6% $4s^24p^26d(^3P)^4P$
	244439.6	244409.0	30.6	89% $4s^24p^26d(^3P)^4P$ + 4% $4s^24p^26d(^3P)^4D$
	-	244678.0	-	82% $4s^24p^26d(^3P)^2P$ + 13% $4s^24p^26d(^3P)^4D$
	245552.0	245424.0	128.0	97% $4s^24p^26s(^1S)^2S$
	-	255915.0	-	96% $4s^24p^26d(^1D)^2P$
	-	256836.0	-	93% $4s^24p^26d(^1D)^2S$
	-	262581.0	-	96% $4s4p^35p((^4S)^5S)^4P$
	-	270566.0	-	98% $4s^24p^27s(^1S)^2S$
3/2	104120.2	104123.0	-2.8	86% $4s4p^4(^3P)^4P$ + 12% $4s^24p^24d(^3P)^4P$
	124094.6	124208.0	-113.4	67% $4s4p^4(^1D)^2D$

			+ 23%$4s^24p^24d(^1D)^2D$
135149.2	134850.0	299.2	64% $4s^24p^24d(^3P)^2P$
			+23%$4s4p^4(^3P)^2P$
			+6%$4s^24p^24d(^1D)^2P$
139782.2	139903.0	-120.8	93% $4s^24p^24d(^3P)^4F$
146379.6	146276.0	103.6	92% $4s^24p^24d(^3P)^4D$
147662.2	147574.0	88.2	95% $4s^24p^25s(^3P)^4P$
153855.5	153777.0	78.5	86% $4s^24p^25s(^3P)^2P$
			+ 8%$4s^24p^25s(^1D)^2D$
161167.3	161607.0	-439.7	70% $4s^24p^25s(^1D)^2D$
			+ 12%$4s^24p^24d(^3P)^2D$
			+ 7%$4s^24p^25s(^3P)^2P$
			+ 6%$4s^24p^24d(^1S)^2D$
163657.6	163641.0	16.6	80% $4s^24p^24d(^3P)^4P$
			+ 11%$4s4p^4(^3P)^4P$
167704.0	167636.0	68.0	56% $4s^24p^24d(^3P)^2D$
			+ 19%$4s^24p^25s(^1D)^2D$
			+ 17%$4s^24p^24d(^1S)^2D$
172128.1	172214.0	-85.9	51% $4s^24p^24d(^1D)^2P$
			+ 41% $4s4p^4(^3P)^2P$
178151.8	178130.0	21.8	60% $4s^24p^24d(^1D)^2D$
			+ 17%$4s4p^4(^1D)^2D$
			+ 9%$4s^24p^24d(^1D)^2P$
181346.5	181648.0	-301.5	26% $4s^24p^24d(^1D)^2P$
			+25%$4s^24p^24d(^3P)^2P$
			+25%$4s4p^4(^3P)^2P$
			+ 9%$4s^24p^24d(^1D)^2D$
186939.2	187111.0	-171.8	67% $4s^24p^24d(^1S)^2D$
			+ 21%$4s^24p^24d(^3P)^2D$
			+ 5%$4s^24p^25d(^3P)^2D$
211697.1	211683.0	14.1	78% $4s^24p^25d(^3P)^4F$
			+ 12%$4s^24p^25d(^3P)^4D$
213007.3	212939.0	68.3	91% $4s^24p^26s(^3P)^4P$
			+ 8%$4s^24p^26s(^3P)^2P$
214868.8	214875.0	-6.2	45% $4s^24p^25d(^3P)^4D$
			+ 20%$4s^24p^25d(^3P)^2P$
			+ 17%$4s^24p^25d(^3P)^4F$
			+ 12%$4s^24p^25d(^3P)^4P$
216384.9	216426.0	-41.1	38% $4s^24p^26s(^3P)^2P$
			+ 26%$4s^24p^25d(^3P)^2P$
			+19%$4s^24p^25d(^3P)^4D$
			+ 5%$4s^24p^26s(^3P)^4P$
217515.1	217376.0	139.1	45% $4s^24p^26s(^3P)^2P$
			+ 32% $4s^24p^25d(^3P)^2P$
			+ 4%$4s^24p^25d(^3P)^2D$
218911.9	218778.0	133.9	74% $4s^24p^25d(^3P)^4P$
			+ 18%$4s^24p^25d(^3P)^4D$
221974.3	222267.0	-292.7	77% $4s^24p^25d(^3P)^2D$
			+ 6%$4s^24p^25d(^3P)^2P$
226807.7	226955.0	-147.3	91% $4s^24p^26s(^1D)^2D$
			+ 5%$4s^24p^26s(^3P)^2P$
230184.6	230176.0	8.6	86% $4s^24p^25d(^1D)^2D$
			+ 5%$4s^24p^25d(^1D)^2P$
231541.4	231226.0	315.4	83% $4s^24p^25d(^1D)^2P$
			+ 5%$4s^24p^25d(^3P)^2P$
			+ 4%$4s^24p^25d(^1D)^2D$
238425.1	238399.0	26.1	63% $4s^24p^26d(^3P)^4F$
			+17%$4s^24p^26d(^3P)^4D$
			+ 9%$4s^24p^26d(^3P)^2P$
			+ 5%$4s^24p^26d(^3P)^2D$

	240114.0	240273.0	-159.0	87% $4s^24p^27s(^3P)^4P$
				+ 12%$4s^24p^27s(^3P)^2P$
	241206.0	240957.0	249.0	31% $4s^24p^26d(^3P)^4F$
				+ 27%$4s^24p^26d(^3P)^2P$
				+ 26%$4s^24p^26d(^3P)^4D$
				+ 14%$4s^24p^26d(^3P)^4P$
	241954.5	241862.0	92.5	35% $4s^24p^26d(^3P)^2P$
				+ 25%$4s^24p^26d(^3P)^4D$
				+ 23%$4s^24p^26d(^3P)^2D$
				+ 10%$4s^24p^26d(^3P)^4P$
	244186.6	243518.0	668.6	82% $4s^24p^27s(^3P)^2P$
				+ 11%$4s^24p^27s(^3P)^4P$
				+ 6%$4s^24p^27s(^1D)^2D$
	244342.0	244264.0	78.0	69% $4s^24p^26d(^3P)^4P$
				+ 22%$4s^24p^26d(^3P)^4D$
	-	244594.0	-	38% $4s^24p^25d(^1S)^2D$
				+ 28%$4s^24p^26d(^3P)^2D$
				+ 20%$4s^24p^26d(^3P)^2P$
				+ 6%$4s^24p^26d(^3P)^4D$
	247102.0	247310.0	-208.0	51% $4s^24p^25d(^1S)^2D$
				+ 35%$4s^24p^26d(^3P)^2D$
	253753.0	253759.0	-6.0	93% $4s^24p^27s(^1D)^2D$
				+ 5%$4s^24p^27s(^3P)^2P$
	-	255445.0	-	99% $4s4p^35p((^4S)^5S)^6P$
	255875.0	255703.0	172.0	90% $4s^24p^26d(^1D)^2D$
	256337.4	256373.0	-35.6	89% $4s^24p^26d(^1D)^2P$
	-	262434.0	-	96% $4s4p^35p((^4S)^5S)^4P$
	-	273182.0	-	97% $4s^24p^26d(^1S)^2D$
5/2	101524.2	101421.0	103.2	86% $4s4p^4(^3P)^4P$
				+ 12%$4s^24p^24d(^3P)^4P$
	124737.0	124713.0	24.0	69% $4s4p^4(^1D)^2D$
				+ 24%$4s^24p^24d(^1D)^2D$
	140735.6	140864.0	-128.4	90% $4s^24p^24d(^3P)^4F$
				+ 7%$4s^24p^24d(^3P)^4D$
	145165.3	145070.0	95.3	37% $4s^24p^24d(^1D)^2F$
				+ 32%$4s^24p^24d(^3P)^2F$
				+ 25%$4s^24p^24d(^3P)^4D$
	147548.6	147499.0	49.6	64% $4s^24p^24d(^3P)^4D$
				+ 14%$4s^24p^24d(^3P)^2F$
				+ 14%$4s^24p^24d(^1D)^2F$
				+ 4%$4s^24p^24d(^3P)^4F$
	150251.3	150172.0	79.3	94% $4s^24p^25s(^3P)^4P$
	161199.5	161760.0	-560.5	59% $4s^24p^25s(^1D)^2D$
				+ 28%$4s^24p^24d(^3P)^4P$
	162615.2	162507.0	108.2	55% $4s^24p^24d(^3P)^4P$
				+ 28%$4s^24p^25s(^1D)^2D$
				+ 7%$4s4p^4(^3P)^4P$
	170107.1	170196.0	-88.9	69% $4s^24p^24d(^3P)^2D$
				+ 9%$4s^24p^24d(^1S)^2D$
				+ 5%$4s^24p^25s(^1D)^2D$
				+ 5%$4s^24p^24d(^3P)^2F$
	175174.3	174993.0	181.3	40%$4s^24p^24d(^3P)^2F$
				+ 40%$4s^24p^24d(^1D)^2F$
				+ 9%$4s^24p^24d(^1S)^2D$
	178651.8	178379.0	272.8	67% $4s^24p^24d(^1D)^2D$
				+ 16%$4s4p^4(^1D)^2D$
				+ 10%$4s^24p^24d(^1S)^2D$
	186145.3	186074.0	71.3	62% $4s^24p^24d(^1S)^2D$
				+ 16%$4s^24p^24d(^3P)^2D$

			$+ 5\%4s4p^4(^1D)^2D$
212438.9	212398.0	40.9	$60\%\ 4s^24p^25d(^3P)^4F$
			$+ 25\%4s^24p^25d(^3P)^4D$
			$+ 7\%4s^24p^25d(^3P)^4P$
			$+ 4\%4s^24p^25d(^3P)^2F$
215086.3	215050.0	36.3	$33\%4s^24p^25d(^3P)^4P$
			$+ 30\%4s^24p^25d(^3P)^4F$
			$+ 19\%4s^24p^25d(^3P)^4D$
			$+ 12\%4s^24p^26s(^3P)^4P$
215915.0	215771.0	144.0	$81\%4s^24p^26s(^3P)^4P$
			$+ 6\%4s^24p^25d(^3P)^4D$
			$+ 4\%4s^24p^26s(^1D)^2D$
			$+ 4\%4s^24p^25d(^3P)^4F$
216880.3	217053.0	-172.7	$72\%\ 4s^24p^25d(^3P)^2F$
			$+ 12\%4s^24p^25d(^3P)^4P$
			$+ 11\%4s^24p^25d(^1D)^2F$
218426.3	218326.0	100.3	$46\%\ 4s^24p^25d(^3P)^4D$
			$+ 41\%4s^24p^25d(^3P)^4P$
			$+ 4\%4s^24p^25d(^3P)^2F$
222017.7	222234.0	-216.3	$77\%\ 4s^24p^25d(^3P)^2D$
			$+ 11\%4s^24p^25d(^1D)^2F$
			$+ 5\%4s^24p^25d(^1D)^2D$
226677.5	226869.0	-191.5	$93\%\ 4s^24p^26s(^1D)^2D$
			$+ 5\%4s^24p^26s(^3P)^4P$
229168.9	229381.0	-212.1	$62\%\ 4s^24p^25d(^1D)^2F$
			$+ 17\%4s^24p^25d(^1D)^2D$
			$+ 8\%4s^24p^25d(^3P)^2F$
230894.3	230971.0	-76.7	$69\%\ 4s^24p^25d(^1D)^2D$
			$+ 10\%4s^24p^25d(^1D)^2F$
			$+ 9\%4s^24p^25d(^3P)^2D$
238829.0	238827.0	2.0	$39\%\ 4s^24p^26d(^3P)^4F$
			$+ 32\%4s^24p^26d(^3P)^4D$
			$+ 16\%4s^24p^26d(^3P)^4P$
			$+ 8\%4s^24p^26d(^3P)^2F$
241035.0	241198.0	-163.0	$48\%\ 4s^24p^26d(^3P)^4F$
			$+ 39\%4s^24p^26d(^3P)^4P$
			$+ 6\%4s^24p^26d(^3P)^4D$
			$+ 5\%4s^24p^26d(^3P)^2D$
242178.6	242471.0	-292.4	$75\%\ 4s^24p^26d(^3P)^2F$
			$+ 7\%4s^24p^26d(^3P)^2D$
			$+ 6\%4s^24p^26d(^3P)^4P$
243028.0	243019.0	9.0	$93\%\ 4s^24p^27s(^3P)^4P$
			$+ 5\%4s^24p^27s(^1D)^2D$
244205.0	244065.0	140.0	$54\%\ 4s^24p^26d(^3P)^4D$
			$+ 33\%4s^24p^26d(^3P)^4P$
			$+ 7\%4s^24p^26d(^3P)^4F$
244940.0	244647.0	293.0	$57\%\ 4s^24p^25d(^1S)^2D$
			$+ 30\%4s^24p^26d(^3P)^2D$
246841.0	247027.0	-186.0	$47\%\ 4s^24p^26d(^3P)^2D$
			$+ 39\%4s^24p^25d(^1S)^2D$
			$+ 6\%4s^24p^26d(^1D)^2F$
253717.0	253732.0	-15.0	$94\%4s^24p^27s(^1D)^2D$
			$+5\%4s^24p^27s(^3P)^4P$
-	255555.0	-	$63\%4s^24p^26d(^1D)^2F$
			$+ 29\%4s^24p^26d(^1D)^2D$
-	255707.0	-	$99\%\ 4s4p^35p((^4S)^5S)^6P$
255920.0	256042.0	-122.0	$63\%\ 4s^24p^26d(^1D)^2D$
			$+ 25\%4s^24p^26d(^1D)^2F$
			$+ 5\%4s^24p^26d(^3P)^2D$
-	262304.0	-	$96\%4s4p35p((^4S)^5S)^4P$

	-	273058.0	-	$98\%4s^24p^26d(^1S)^2D$
7/2	142228.8	142391.0	-162.2	$91\%4s^24p^24d(^3P)^4F$ $+6\%4s^24p^24d(^3P)^4D$
	146163.1	146123.0	40.1	$52\%4s^24p^24d(^3P)^4D$ $+25\%4s^24p^24d(^1D)^2F$ $+16\%4s^24p^24d(^3P)^2F$
	150446.2	150444.0	2.2	$39\%4s^24p^24d(^3P)^4D$ $+29\%4s^24p^24d(^1D)^2F$ $+26\%4s^24p^24d(^3P)^2F$
	160150.7	160290.0	-139.3	$95\%4s^24p^24d(^1D)^2G$
	175402.0	175301.0	101.0	$53\%4s^24p^24d(^3P)^2F$ $+39\%4s^24p^24d(^1D)^2F$
	214258.0	214267.0	-9.0	$72\%4s^24p^25d(^3P)^4F$ $+24\%4s^24p^25d(^3P)^4D$
	217161.7	217140.0	21.7	$59\%4s^24p^25d(^3P)^4D$ $+24\%4s^24p^25d(^3P)^4F$ $+8\%4s^24p^25d(^1D)^2F$ $+7\%4s^24p^25d(^3P)^2F$
	220337.7	220561.0	-223.3	$74\%4s^24p^25d(^3P)^2F$ $+13\%4s^24p^25d(^3P)^4D$ $+7\%4s^24p^25d(^1D)^2G$
	227864.6	227846.0	18.6	$52\%4s^24p^25d(^1D)^2G$ $+45\%4s^24p^25d(^1D)^2F$
	229133.0	229238.0	-105.0	$42\%4s^24p^25d(^1D)^2F$ $+40\%4s^24p^25d(^1D)^2G$ $+12\%4s^24p^25d(^3P)^2F$
	240998.7	240904.0	94.7	$61\%4s^24p^26d(^3P)^4F$ $+33\%4s^24p^26d(^3P)^4D$ $+6\%4s^24p^26d(^3P)^2F$
	243792.0	243688.0	104.0	$53\%4s^24p^26d(^3P)^4D$ $+36\%4s^24p^26d(^3P)^4F$ $+5\%4s^24p^26d(^1D)^2F$
	245342.0	245621.0	-279.0	$82\%4s^24p^26d(^3P)^2F$ $+10\%4s^24p^26d(^3P)^4D$ $+5\%4s^24p^26d(^1D)^2G$
	254969.7	254938.0	31.7	$52\%4s^24p^26d(^1D)^2F$ $+44\%4s^24p^26d(^1D)^2G$
	255429.7	255472.0	-42.3	$50\%4s^24p^26d(^1D)^2G$ $+42\%4s^24p^26d(^1D)^2F$ $+4\%4s^24p^26d(^3P)^2F$
	-	256142.0	-	$99\%4s4p^35p((^4S)^5S)^6P$
9/2	144157.5	144362.0	-204.5	$96\%4s^24p^24d(^3P)^4F$
	161025.0	160829.0	196.0	$96\%4s^24p^24d(^1D)^2G$
	216525.5	216566.0	-40.5	$94\%4s^24p^25d(^3P)^4F$ $+5\%4s^24p^25d(^1D)^2G$
	228384.8	228391.0	-6.2	$95\%4s^24p^25d(^1D)^2G$ $+5\%4s^24p^25d(^3P)^4F$
	-	243521.0	-	$95\%4s^24p^26d(^3P)^4F$ $+5\%4s^24p^26d(^1D)^2G$
	-	255178.0	-	$95\%4s^24p^26d(^1D)^2G$ $+5\%4s^24p^26d(^3P)^4F$

[a]Difference between experimental and calculated energy levels.
[b]This level was not fitted due to interaction, so not included in LSF calculation.

Table 3.4: LSF and HFR parameters of odd configurations of Br III in cm^{-1}.

configuration	parameter	LSF	accuracy	HF	LSF/HF
$4s^24p^3$	$E_{av}(4s^24p^3)$	20737.9	2072.0	21969.0	
	$F^2(4p,4p)$	40041.0	2401.0	56580.3	0.708
	$\alpha(4p)$	312.2	179.0		
	$\xi(4p)$	3302.8	339.0	3022.7	1.093
$4s^24p^25p$	$E_{av}(4s^24p^25p)$	185778.3	239.0	189834.2	0.983
	$F^2(4p,4p)$	49415.2	411.0	59358.1	0.832
	$\alpha(4p)$	0.0	43.0		
	$\xi(4p)$	3655.5	183.0	3363.2	1.087
	$\xi(5p)$	555.3	(fixed)	555.4	1.000
	$F^1(4p,5p)$	0.0	(fixed)	0.0	
	$F^2(4p,5p)$	11738.3	669.0	14260.5	0.823
	$G^0(4p,5p)$	2835.3	102.0	3555.5	0.797
	$G^1(4p,5p)$	0.0	(fixed)	0.0	
	$G^2(4p,5p)$	3449.2	124.0	4325.4	0.797
$4s^24p^26p$	$E_{av}(4s^24p^26p)$	237152.1	(fixed)	237152.9	1.006
	$F^2(4p,4p)$	50604.9	(fixed)	59535.3	0.850
	$\alpha(4p)$	0.0	(fixed)		
	$\xi(4p)$	3382.4	(fixed)	3382.4	1.000
	$\xi(6p)$	228.5	(fixed)	228.5	1.000
	$F^1(4p,6p)$	0.0	(fixed)	0.0	
	$F^2(4p,6p)$	4498.1	(fixed)	5292.0	0.850
	$G^0(4p,6p)$	888.3	(fixed)	1184.4	0.750
	$G^1(4p,6p)$	0.0	(fixed)	0.0	
	$G^2(4p,6p)$	1157.8	(fixed)	1543.8	0.750
$4s^24p^24f$	$E_{av}(4s^24p^24f)$	229227.6	61.0	231249.0	0.996
	$F^2(4p,4p)$	51605.1	489.0	59469.5	0.868
	$\alpha(4p)$	0.0	(fixed)		
	$\xi(4p)$	3379.9	(fixed)	3379.9	1.000
	$\xi(4f)$	0.6	(fixed)	0.6	1.000
	$F^1(4p,4f)$	0.0	(fixed)	0.0	
	$F^2(4p,4f)$	8415.7	396.0	9429.7	0.892
	$G^2(4p,4f)$	2894.4	424.0	3574.4	0.810
	$G^3(4p,4f)$	0.0	(fixed)	0.0	
	$G^4(4p,4f)$	1897.8	278.0	2343.6	0.810
$4s^24p^25f$	$E_{av}(4s^24p^25f)$	254968.4	(fixed)	254963.3	1.005
	$F^2(4p,4p)$	50618.2	(fixed)	59550.9	0.850
	$\alpha(4p)$	0.0	(fixed)		
	$\xi(4p)$	3386.0	(fixed)	3386.0	1.000
	$\xi(5f)$	0.3	(fixed)	0.3	1.000
	$F^1(4p,5f)$	0.0	(fixed)	0.0	
	$F^2(4p,5f)$	3821.1	(fixed)	4495.4	0.850
	$G^2(4p,5f)$	1666.6	(fixed)	2222.2	0.750
	$G^3(4p,5f)$	0.0	(fixed)	0.0	
	$G^4(4p,5f)$	1102.8	(fixed)	1470.5	0.750
$4s4p^34d$	$E_{av}(4s4p^34d)$	278432.5	(fixed)	278425.1	1.005
	$F^2(4p,4p)$	49278.5	(fixed)	57974.8	0.850
	$\alpha(4p)$	0.0	(fixed)		
	$\xi(4p)$	3212.8	(fixed)	3212.8	1.000
	$\xi(4d)$	120.9	(fixed)	120.9	1.000
	$F^1(4p,4d)$	0.0	(fixed)	0.0	
	$F^2(4p,4d)$	32526.9	(fixed)	38267.0	0.850
	$G^1(4s,4p)$	58733.6	(fixed)	78311.5	0.750
	$G^2(4s,4d)$	20898.4	(fixed)	27864.5	0.750
	$G^1(4p,4d)$	33109.8	(fixed)	44146.5	0.750
	$G^2(4p,4d)$	0.0	(fixed)	0.0	
	$G^3(4p,4d)$	20150.4	(fixed)	26867.3	0.750

$4s4p^3 5s$	$E_{av}(4s4p^3 5s)$	279269.2	(fixed)	279270.1	1.005
	$F^2(4p,4p)$	49995.8	(fixed)	58818.7	0.850
	$\alpha(4p)$	0.0	(fixed)		
	$\xi(4p)$	3315.8	(fixed)	3315.8	1.000
	$G^1(4s,4p)$	59475.8	(fixed)	79301.2	0.750
	$G^0(4s,5s)$	2886.8	(fixed)	3849.1	0.750
	$G^1(4p,5s)$	4317.5	(fixed)	5756.7	0.750
$4s^2 4p^3$ -$4s^2 4p^2 5p$	$R^0(4p,4p;4p,5p)$	1461.0	354.0	1856.7	0.787
	$R^2(4p,4p;4p,5p)$	6808.0	1650.0	8651.6	0.787
$4s^2 4p^3$ -$4s^2 4p^2 6p$	$R^0(4p,4p;4p,6p)$	767.0	186.0	974.7	0.787
	$R^2(4p,4p;4p,6p)$	3398.2	823.0	4318.5	0.787
$4s^2 4p^3$ -$4s^2 4p^2 4f$	$R^2(4p,4p;4p,4f)$	10091.0	2445.0	12823.7	0.787
$4s^2 4p^3$ -$4s^2 4p^2 5f$	$R^2(4p,4p;4p,5f)$	8175.4	1981.0	10389.5	0.787
$4s^2 4p^3$ -$4s4p^3 4d$	$R^1(4s,4p;4p,4d)$	44357.5	10748.0	56369.9	0.787
	$R^2(4s,4p;4d,4p)$	31633.7	7665.0	40199.5	0.787
$4s^2 4p^2 5p$ -$4s^2 4p^2 4f$	$R^2(4p,5p;4p,4f)$	-5425.8	-1315.0	-6895.0	0.787
	$R^2(4p,5p;4f,4p)$	397.4	96.0	505.1	0.787
$4s^2 4p^2 5p$ -$4s4p^3 5s$	$R^1(4s,5p;4p,5s)$	19938.0	4831.0	25337.3	0.787
	$R^0(4s,5p;5s,4p)$	2584.0	(fixed)	3445.5	0.750
	Standard deviation σ	253.0			

The free configuration interaction integrals were linked to vary in the same ratio; the remaining integrals fixed at 75% were not included in the table.

Table 3.5: LSF and HFR parameters of even configurations of Br III in cm^{-1}.

configuration	parameter	LSF	accuracy	HF	LSF/HF
$4s4p^4$	$E_{av}(4s4p^4)$	141487.6	151.0	142120.4	0.996
	$F^2(4p,4p)$	52452.6	657.0	56606.7	0.927
	$\alpha(4p)$	-342.0	-58.0		
	$\xi(4p)$	3328.2	247.0	3029.8	1.098
	$G^1(4s,4p)$	61402.5	347.0	76668.8	0.801
$4s^24p^24d$	$E_{av}(4s^24p^24d)$	163159.1	51.0	163991.0	0.995
	$F^2(4p,4p)$	46339.6	467.0	58026.7	0.799
	$\alpha(4p)$	-141.4	-32.0		
	$\xi(4p)$	3543.3	128.0	3218.1	1.101
	$\xi(4d)$	111.7	(fixed)	111.7	1.000
	$F^2(4p,4d)$	31865.3	488.0	37088.0	0.859
	$G^1(4p,4d)$	33951.4	211.0	42208.5	0.804
	$G^3(4p,4d)$	20090.7	464.0	25681.2	0.782
$4s^24p^25d$	$E_{av}(4s^24p^25d)$	222576.6	48.0	228000.8	0.980
	$F^2(4p,4p)$	45658.8	440.0	59368.5	0.769
	$\xi(4p)$	3640.1	111.0	3357.5	1.084
	$\xi(5d)$	37.0	(fixed)	37.0	1.000
	$F^2(4p,5d)$	7610.8	366.0	9876.7	0.771
	$G^1(4p,5d)$	5378.2	(fixed)	8274.2	0.650
	$G^3(4p,5d)$	3531.2	(fixed)	5432.7	0.650
$4s^24p^26d$	$E_{av}(4s^24p^26d)$	248929.2	61.0	253745.2	0.981
	$F^2(4p,4p)$	48634.8	676.0	59539.4	0.817
	$\xi(4p)$	3585.7	121.0	3379.4	1.061
	$\xi(6d)$	17.7	(fixed)	17.7	1.000
	$F^2(4p,6d)$	3061.0	684.0	4257.3	0.719
	$G^1(4p,6d)$	2500.9	(fixed)	3334.6	0.750
	$G^3(4p,6d)$	1687.2	(fixed)	2249.7	0.750
$4s^24p^25s$	$E_{av}(4s^24p^25s)$	158686.8	88.0	161686.6	0.987
	$F^2(4p,4p)$	51344.7	482.0	58816.7	0.873
	$\alpha(4p)$	-100.0	(fixed)		
	$\xi(4p)$	3481.3	(fixed)	3315.5	1.050
	$G^1(4p,5s)$	4207.6	230.0	5650.8	0.745
$4s^24p^26s$	$E_{av}(4s^24p^26s)$	220803.6	92.0	225948.7	0.980
	$F^2(4p,4p)$	49066.6	523.0	59431.0	0.826
	$\alpha(4p)$	-100.0	(fixed)		
	$\xi(4p)$	3474.2	175.0	3370.6	1.031
	$G^1(4p,6s)$	1262.6	300.0	1634.5	0.772
$4s^24p^27s$	$E_{av}(4s^24p^27s)$	247650.0	93.0	252614.9	0.984
	$F^2(4p,4p)$	46261.6	843.0	59563.3	0.777
	$\xi(4p)$	3384.4	(fixed)	3384.5	1.000
	$G^1(4p,7s)$	547.6	(fixed)	730.2	0.750
$4s4p^35p$	$E_{av}(4s4p^35p)$	306842.0	(fixed)	306836.1	1.004
	$F^2(4p,4p)$	50433.3	(fixed)	59333.4	0.850
	$\xi(4p)$	3361.1	(fixed)	3361.2	1.000
	$\xi(5p)$	560.1	(fixed)	560.1	1.000
	$F^2(4p,5p)$	12248.2	(fixed)	14409.7	0.850
	$G^1(4s,4p)$	59876.9	(fixed)	79835.9	0.750
	$G^1(4s,5p)$	3951.8	(fixed)	5269.1	0.750
	$G^0(4p,5p)$	2560.6	(fixed)	3414.2	0.750
	$G^2(4p,5p)$	3233.5	(fixed)	4311.4	0.750
$4s4p^34f$	$E_{av}(4s4p^34f)$	348792.3	(fixed)	348788.7	1.004
	$F^2(4p,4p)$	50537.4	(fixed)	59455.8	0.850
	$\xi(4p)$	3378.2	(fixed)	3378.3	1.000
	$\xi(4f)$	0.6	(fixed)	0.7	0.857

	$F^2(4p,4f)$	8241.9	(fixed)	9696.4	0.850
	$G^1(4s,4p)$	59984.7	(fixed)	79979.7	0.750
	$G^3(4s,4f)$	1419.7	(fixed)	1893.0	0.750
	$G^2(4p,4f)$	2844.8	(fixed)	3793.1	0.750
	$G^4(4p,4f)$	1863.9	(fixed)	2485.3	0.750
$4p^44d$	$E_{av}(4p^44d)$	416251.3	(fixed)	416244.2	1.003
	$F^2(4p, 4p)$	49257.6	(fixed)	57950.1	0.850
	$\xi(4p)$	3211.9	(fixed)	3212.0	1.000
	$\xi(4d)$	131.3	(fixed)	131.4	0.999
	$F^2(4p,4d)$	33580.9	(fixed)	39507.0	0.850
	$G^1(4p,4d)$	34634.8	(fixed)	46179.9	0.750
	$G^3(4p,4d)$	21086.3	(fixed)	28115.2	0.750
$4p^45s$	$E_{av}(4p^4\,5s)$	420822.1	(fixed)	420820.3	1.003
	$F^2(4p,4p)$	50021.4	(fixed)	58848.8	0.850
	$\xi(4p)$	3320.8	(fixed)	3320.9	1.000
	$G^1(4p,5s)$	4428.7	(fixed)	5905.1	0.750
$4s4p^24d^2$	$E_{av}(4s4p^2\,4d^2)$	426379.5	(fixed)	426373.0	1.003
	$F^2(4p,4p)$	50305.1	(fixed)	59182.5	0.850
	$F^2(4d,4d)$	32452.1	(fixed)	38179.0	0.850
	$F^4(4d,4d)$	21302.3	(fixed)	25061.6	0.850
	$\xi(4p)$	3382.8	(fixed)	3382.9	1.000
	$\xi(4d)$	137.7	(fixed)	137.8	0.999
	$F^2(4p,4d)$	34158.6	(fixed)	40186.6	0.850
	$G^1(4s,4p)$	59820.6	(fixed)	79760.8	0.750
	$G^2(4s,4d)$	22512.1	(fixed)	30016.1	0.750
	$G^1(4p,4d)$	35058.1	(fixed)	46744.1	0.750
	$G^3(4p,4d)$	21399.5	(fixed)	28532.7	0.750
$4s4p^25s^2$	$E_{av}(4s4p^25s^2)$	441328.2	(fixed)	441330.2	1.003
	$F^2(4p,4p)$	51731.3	(fixed)	60860.4	0.850
	$\xi(4p)$	3606.8	(fixed)	3606.8	1.000
	$G^1(4s,4p)$	61309.7	(fixed)	81746.3	0.750
$4s^24p5s5p$	$E_{av}(4s^24p5s5p)$	352342.9	(fixed)	352344.2	1.004
	$\xi(4p)$	3661.0	(fixed)	3661.0	1.000
	$\xi(5p)$	709.2	(fixed)	709.3	1.000
	$F^2(4p,5p)$	13711.1	(fixed)	16130.8	0.850
	$G^1(4p,5s)$	4389.3	(fixed)	5852.4	0.750
	$G^0(4p,5p)$	3196.6	(fixed)	4262.2	0.750
	$G^2(4p,5p)$	3797.7	(fixed)	5063.7	0.750
	$G^1(5s,5p)$	23680.2	(fixed)	31573.6	0.750
$4s4p^24f^2$	$E_{av}(4s4p^24f^2)$	592388.2	(fixed)	592383.6	1.002
	$F^2(4p,4p)$	52577.1	(fixed)	61855.5	0.850
	$F^2(4f,4f)$	19078.1	(fixed)	22444.8	0.850
	$F^4(4f,4f)$	12502.2	(fixed)	14708.6	0.850
	$F^6(4f,4f)$	9167.3	(fixed)	10785.1	0.850
	$\xi(4p)$	3716.9	(fixed)	3716.9	1.000
	$\xi(4f)$	1.1	(fixed)	1.1	1.000
	$F^2(4p,4f)$	11885.5	(fixed)	13983.0	0.850
	$G^1(4s,4p)$	62108.6	(fixed)	82811.5	0.750
	$G^3(4s,4f)$	2892.1	(fixed)	3856.2	0.750
	$G^2(4p,4f)$	5193.3	(fixed)	6924.4	0.750
	$G^4(4p,4f)$	3421.4	(fixed)	4562.0	0.750
$4s4p^4$ -$4s^24p^24d$	$R^1(4p,4p;4s,4d)$	44729.4	216.0	54395.6	0.822
$4s4p^4$ -$4s^24p^25d$	$R^1(4p,4p;4s,5d)$	20039.1	97.0	24369.5	0.822
$4s4p^4$ -$4s^24p^25s$	$R^1(4p,4p;4s,5s)$	156.0	1.0	189.7	0.822
$4s4p^4$ -$4s^24p^26s$	$R^1(4p,4p;4s,6s)$	-251.5	-1.0	-305.8	0.822
$4s^24p^24d$-$4s^24p^25d$	$R^0(4p,4d;4p,5d)$	1388.9	7.0	1689.0	0.822
	$R^2(4p,4d;4p,5d)$	10608.0	51.0	12900.4	0.822
	$R^1(4p,4d;5d,4p)$	14736.9	71.0	17921.7	0.822
	$R^3(4p,4d;5d,4p)$	9272.7	45.0	11276.5	0.822

$4s^24p^24d$-$4s^24p^25s$	$R^2(4p,4d;4p,5s)$	-9335.9	-45.0	-11353.5	0.822
	$R^1(4p,4d;5s,4p)$	-3156.7	-15.0	-3839.0	0.822
$4s^24p^24d$-$4s^24p^26s$	$R^2(4p,4d;4p,6s)$	-4297.6	-21.0	-5226.2	0.822
	$R^1(4p,4d;6s,4p)$	-1934.8	-9.0	-2352.9	0.822
	Standard deviation σ	213.0			

The free configuration interaction integrals (R^k) were linked to vary in the same ratio; the remaining integrals fixed at 70% were not included in the table.

CHAPTER 4

The spectrum of trebly ionized bromine: Br IV

The three-times ionized bromine (Br IV) has neutral germanium- like (Ge I) spectrum with $3d^{10}4s^24p^2$ as the ground state configuration with the five levels $^3P_{0,1,2}$, $^1D_2$ and $^1S_0$. $^3P_0$ being the ground most level. The excited configurations are $4s4p^3$, $4s^24pnd$ ($n \geq 4$) and $4s^24pns$ ($n \geq 5$); and further excitations lead to $3d^{10}4s^24p$ (5p+6p+4f+5f), $3d^{10}4s$ ($4p^24d+4p^25s$) and $3d^{10}$ $4p^4$.

Tauheed et al [1] revised the earlier work of Joshi and Budhiraja [2]. They studied the $4s^24p^2$–[$4s4p^3$ + $4s^24p$ (4d + 5d + 6d + 5s + 6s + 7s)] transition arrays in the wavelength region 320-1290Å and reported one hundred and forty-two classified lines connecting 61 energy levels. They also reported the ionization limit at 385400±250 cm^{-1} (47.77±0.03 eV). The present investigation was undertaken mainly due to the availability of extended data on bromine spectrum which led us to extend the study of new excited configurations $3d^{10}4s^24p$ (5p+4f+5f), $3d^{10}4s$ $4p^2$(4d+5s) and $3d^{10}$ $4p^4$. The study of these new configurations is the only way one can establish the unknown levels ($^3F_4$) of the earlier reported configurations 4p4d, 4p5d and 4p6d. The $^3F_4$ level cannot combine radiatively with the ground configuration as the highest J value of any ground level is only 2. This can be established through the observed transitions from 4p5p as well as from 4p4f levels. Further 4p5d and 4p6d level values were based on shorter wavelengths and hence can be improved through these transitions. This prompted us to undertake this investigation.

4.1 Energy level structure:

The electronic distribution for ground state configuration of three times ionized bromine (Br IV) $1s^2$, $2s^22p^6$, $3s^23p^6$, $3d^{10}4s^24p^2$ gives rise to energy levels (^{2}P) $^3P_{0,1,2}$, (^{2}P) $^1D_2$ and (^{2}P) $^1S_0$ in order of increasing energy.

The excited configurations of interest with their associated levels are listed below:

$4s4p^3$	(^{4}S)	$^5S_2$
		$^3S_1$
	(^{2}D)	$^3D_{1,2,3}$
		$^1D_2$
	(^{2}P)	$^3P_{0,1,2}$
		$^1P_1$
$4p^4$		$^3P_{0,1,2}$
		$^1D_2$
		$^1S_0$
4pns(n≥5)		$^3P_{0,1,2}$
		$^1P_1$
		$^3D_{1,2,3}$
4pnp(n≥5)		$^3P_{0,1,2}$
		$^3S_1$
		$^1D_2$
		$^1P_1$
		$^1S_0$
4pnd(n≥4)		$^3F_{2,3,4}$
		$^3D_{1,2,3}$
		$^3P_{0,1,2}$
		$^1F_3$
		$^1D_2$
		$^1P_1$
4pnf(n≥4)		$^3G_{3,4,5}$
		$^3F_{2,3,4}$
		$^3D_{1,2,3}$
		$^1G_4$
		$^1F_3$
		$^1D_2$
4png (n≥5)		$^3F_{2,3,4}$
		$^3G_{3,4,5}$
		$^3H_{4,5,6}$

		$^1F_3$
		$^1G_4$
		$^1H_5$
$4s4p^24d$	$(^3P)(^4P)$	$^5F_{1,2,3,4,5}$
		$^5D_{0,1,2,3,4}$
		$^5P_{1,2,3}$
		$^3F_{a2,3,4}$
		$^3D_{a1,2,3}$
		$^3P_{a0,1,2}$
	$(^3P)(^2P)$	$^3F_{b2,3,4}$
		$^3D_{b1,2,3}$
		$^3P_{b0,1,2}$
		$^1F_3$
		$^1D_2$
		$^1P_1$
	$(^1D)(^2D)$	$^3G_{3,4,5}$
		$^3F_{2,3,4}$
		$^3D_{1,2,3}$
		$^3P_{0,1,2}$
		$^3S_1$
		$^1G_4$
		$^1F_3$
		$^1D_2$
		$^1P_1$
		$^1S_0$
	$(^1S)(^2S)$	
		$^3D_{1,2,3}$
		$^1D_2$
$4s4p^25s$	$(^3P)(^4P)$	$^5P_{1,2,3}$
		$^3P_{a0,1,2}$
	$(^3P)(^2P)$	$^3P_{b0,1,2}$
		$^1P_1$
	$(^1D)(^2D)$	$^3D_{1,2,3}$
		$^1D_2$
	$(^1S)(^2S)$	$^3S_1$
		$^1S_0$

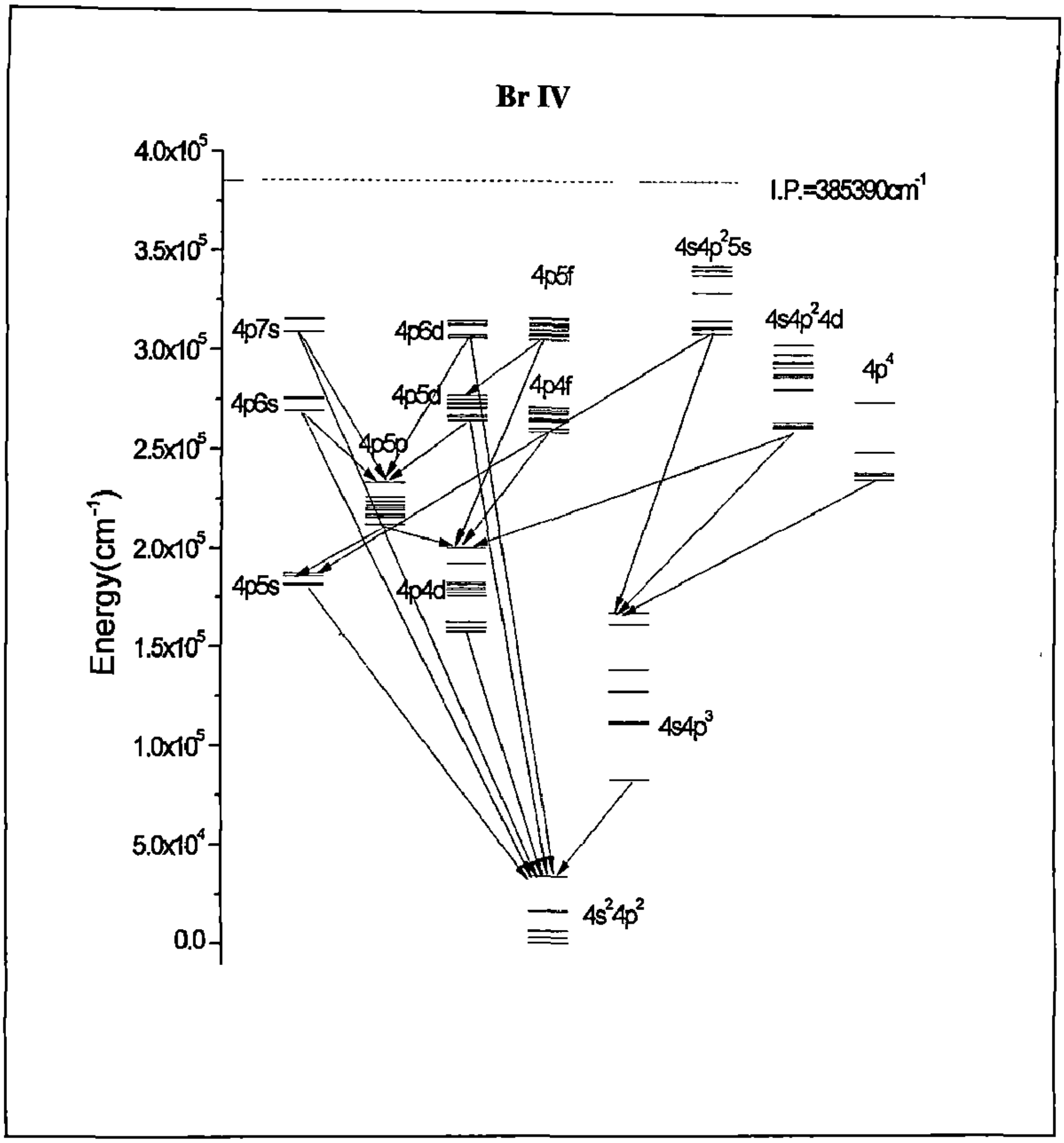

Fig. 4.1: Energy level diagram of Br IV. The configurations shown in black colour are analyzed in earlier work [1] and that shown in red colour are studied in the present work.

4.2 Theoretical calculations: The theoretical predictions for this spectrum were obtained by using Cowan's code [3] in HFR mode. The prominent interacting configurations included for even parity system were $3d^{10}4s^24p$ (5p+6p+4f+5f), $3d^{10}4s$ ($4p^24d+4p^25s$) and $3d^{10}$ $4p^4$, and that for odd parity matrix were $3d^{10}4s4p^3$, $3d^{10}4s^24p$ (4d + 5d + 6d + 7d + 5s + 6s + 7s + 8s), $4s4p^25p$, $4s4p^24f$, $4p^34d$, $4p^35s$, $4s^24p5g$, $4s4p4d^2$ and $4s4p5s^2$ for a reliable prediction. The *ab initio* values for different energy parameters were used as E_{av} and ζ at 100%, F^k at 85%, G^k and R^k at 75% of HFR values. Further, this scaling was refined by comparing the parameters with its isoelectronic ions Kr^{4+} [4, 5] and Rb^{5+} [6].

4.3 Analysis and Discussions:

4.31 Earlier analysis:

The spectrum of Br IV was earlier analyzed by Rao and Krishnamurty [7]. They studied $4p^2$, 4p (4d+5s+5p) configurations. The entire analysis was revised by Joshi and Budhiraja [2] and extended to include 4p6s configuration. Recently, Tauheed et al. [1] investigated the Br IV spectrum in more detail. They investigated the $4s^24p^2$ – [$4s4p^3$ + $4s^24p$ (4d+5d+6d+5s+6s+7s)] transition array with theoretical predictions by Cowan's code [3] and spectral recordings on grazing as well as normal incidence spectrographs in the wavelength region 319 - 1291Å. Out of 34 levels reported by Joshi and Budhiraja [2] excluding 4p5p configuration, only 12 levels could be confirmed (6 levels with same designation and 6 others with changed designation). The missing level of the ground configuration $4s^24p^2$ $^1S_0$ was established however, $4s4p^3$ $^5S_2$ was neither confirmed nor any new value was given. Apart from this, a tentative 4p4d $^3F_4$ level value was also assigned.

4.32 New Analysis:

Firstly, large number of odd parity levels of Joshi and Budhiraja [2] were revised by Tauheed et al [1], but the presently known even parity levels of 4p5p configuration reported by Joshi and Budhiraja certainly require further investigation. Secondly, 4p4f configuration was completely untouched which is expected to give strong transitions to 4p4d levels, was the main motivation of the present analysis. Mostly the same plates were used for this analysis as was used in ref [1] except an extended line list above 2000 Å by Budhiraja [8] which became available to us only recently.

We started the analysis from the beginning and soon came to the conclusion that all the reported levels in ref [1] were found to be correct and we confirmed them all except $4s^24p4d$ $^3F_4$ at this stage. As mentioned earlier the $4s4p^3$ $^5S_2$ level was not reported by Tauheed et al [1], and has now been found at 82805.1 cm^{-1} based on the identification of three transitions at 1247.209, 1295.537 and 1501.222 Å from $4s^24p^2$ $^3P_1$, $^3P_2$ and $^1D_2$ respectively with the right ionization characteristics. This level is now fitting nicely in LSF calculations. The earlier value was deviating more than 1200 cm^{-1}. Moreover, one of the earlier classified lines at 1228.041 Å for this level did not satisfy the Br IV characteristic on our plate. Therefore, this level value was rejected.

4.33 The $4s^24p5p$ configuration: This configuration arises from the excitation of $4s^24p4d$ and $4s^24p5s$ configurations. This array [$4s^24p4d+4s^24p5s - 4s^24p5p$] was found to be reasonably strong on our plates. Since the configurations $4s4p^3$, 4p4d and 4p5s are strongly mixed with each other, therefore moderately strong transitions from $4s4p^3$ were also found on our plates and we were successful to establish all the ten levels of this configuration. The LS purity of all the levels is greater than 50% except $^3D_1$ at 215415.6 cm^{-1} which is 46%. Thus LS designation is still quite unambiguous. The only thing we noticed was that $^1P_1$ lies below $^3P_1$ though we normally expect other way around. The $^1P_1$ at 212005.2 cm^{-1} having 55% leading purity is thus unambiguous though its second component is 41% $^3D_1$. All the levels agree well with the calculated values. We should point out that some of the transitions of this array lie above 2000Å were taken from the Budhiraja's list [8]. However, because of the strong interaction with $4s4p^24d$ configuration, fairly strong transitions were also observed between $4s4p^3$- 4p5p which lie in the shorter wavelength region of our plates. They were quite helpful to confirm the ionization stage of the observed lines and hence the confirmation of the 4p5p levels.

The advantage of having established 4p5p $^3D_3$ level was that the 4p4d $^3F_4$ level can now be confirmed. It was noticed that the line assigned previously to this level was not very satisfactory and we had a very strong unassigned line with Br IV character at 1729.822Å on our plate. This prompted us to assign this line as 4p5p $^3D_3$-4p4d $^3F_4$ transition which yielded the level value of 4p4d $^3F_4$ at 162534.6 cm^{-1}.

4.34 The $4s^24p4f$ configuration: The *ab initio* calculations were obtained with the inclusion of the interacting configurations as mentioned-above. Almost all the transitions between 4p4d and 4p4f lie on our plates and they were predicted to be quite strong. It was not very difficult to locate the first level $^3D_2$ of 4p4f configuration at 268362.3 cm^{-1} based on the identifications of 10 transitions. This establishes the initial shift from the calculated values. A further scaling of the E_{av} (4p4f) gave very precise prediction of the remaining 4p4f levels. This configuration also gives moderate transitions with $4s4p^3$ due to strong mixing with $4s4p^24d$ as mentioned above. As a result, all the 12 levels of this configuration were established satisfactorily. However, their LS designations were not very unambiguous. There was no problem with J=1 ,2 and 5 levels as their leading LS purities were greater than 50% but in J=3 matrix, only $^3D_3$ was pure enough to be unambiguous but $^3G_3$, $^3F_3$ and $^1F_3$ were highly mixed with each other with leading purities less than 50%. The $^3G_3$ and $^3F_3$ levels were assigned their first leading component but $^1F_3$ at 263963 cm^{-1} was chosen as the second highest component. A similar situation is noticed in J=4 levels also. Only $^1G_4$ is 91% pure but $^3G_4$ and $^3F_4$ are strongly mixed with each other showing LS purities as 45% and 47% respectively. However, it was not difficult to name them as they appear in the least squares fit. The least squares fitted energy parameters were found to be in close agreement with Kr V [4] which is isoelectronic with Br IV.

4.35 The $4s4p^2 4d$ +$4s4p^2 5s$ + $4p^4$ + 4p5f configurations:

These configurations along with 4p6p possess a very complicated structure. Two configurations namely $4s4p^2 4d$ and $4s4p^2 5s$ alone contain 72 levels. Almost all the levels of $4p^4$, 4p5f as well as 4p6p are within the energy spread of these two configurations. Thus making analysis very difficult. We have tried to study these configurations as their transitions lie in our wavelength region. We could establish 17 levels of $4s4p^2 4d$, 3 levels of $4s4p^2 5s$, 11 levels of 4p5f and 5 levels of $4p^4$ configurations. We also tried to locate the 4p6p levels but their transitions were too weak to confirm any level, consequently were not included here.

4.4 Results:

The levels were optimized using a program LOPT [9] provided to us by Dr. Kramida of NIST [USA]. The transition probabilities (gA) and weighted oscillator strength (log gf) as obtained with final least squares fitted energy parameters are included in Table 4.1. The optimized levels are given in Table 4.2 along with their uncertainties and the number of connecting lines as obtained by LOPT program. The least squares fitted energy levels along with their LS percentage mixing are assembled in Table 4.3 and the corresponding energy parameters of both even and odd parity configurations are given in Table 4.4 and 4.5 respectively. 120 levels of Br IV have now been established, 58 being new. Among 424 classified spectral lines, 277 are new. We found reasonably good agreement of observed levels with the theoretical calculations.

The standard deviations for even and odd parity configurations were 299 and 264 cm^{-1} respectively.

4.41 Ionization potential:

Tauheed et al. [1] reported the ionization limit of Br IV at 385400 ± 250 cm^{-1} based on three member series 4p*n*d (*n* = 4–6) and 4p*n*s (*n* = 5–7). To have more accurate value of ionization potential, we certainly need ng or nh series. Unfortunately, at this stage these series are not known. Since the LS purity of $^3P_2$ level in *n*s series and $^1F_3$ level in *n*d series were consistently high, therefore, they were considered for the determination of ionization potential. The limit obtained from $^3P_2$ level of *n*s series was 385351.8 and from $^1F_3$ level of *n*d series was 385427.2 cm^{-1} using Ritz's formula [10]. Therefore, the mean value of ionization potential of Br IV was adapted at 385390±100 cm^{-1} (47.782 ± 0.012 eV).

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Table 4.1: Classified lines of Br IV.

I_{obs}[c]	λ_{obs} (Å)	σ_{obs} (cm^{-1})	λ_{Ritz} (Å)	λ_{obs}-λ_{Ritz}[d] (Å)	Lower Level	Upper level	Log gf	gA (s^{-1})[e]
5	319.529[a]	312961	319.529	0	$4s^24p^2$ $^3P_0$	4p6d $^3P_1$	-3.705	1.29E+07
18	319.748[a]	312746	319.7464	0.002	$4s^24p^2$ $^3P_1$	4p7s $^3P_2$	-1.703	1.294E+09
9	320.504[a]	312009	320.504	0	$4s^24p^2$ $^3P_1$	4p6d $^1P_1$	-3.62	1.554E+07
21	322.571[a]	310009	322.5726	-0.002	$4s^24p^2$ $^3P_1$	4p6d $^1D_2$	-1.582	1.678E+09
34	322.833[a]	309758	322.8335	0	$4s^24p^2$ $^3P_2$	4p7s $^3P_2$	-1.306	3.167E+09
15	322.999[a]	309598	322.999	0	$4s^24p^2$ $^3P_1$	4p6d $^3P_0$	-1.582	1.678E+09
21	323.229[a]	309378	323.2223	0.007	$4s^24p^2$ $^3P_0$	4p7s $^3P_1$	-1.873	8.551E+08
19	324.946[a]	307743	324.9488	-0.003	$4s^24p^2$ $^3P_2$	4p6d $^3D_3$	-1.058	5.503E+09
29	325.496[a]	307223	325.4996	-0.004	$4s^24p^2$ $^3P_2$	4p6d $^3D_2$	-1.332	2.934E+09
12	325.715[a]	307017	325.7149	0	$4s^24p^2$ $^3P_2$	4p6d $^1D_2$	-1.813	9.649E+08
9	325.986[a]	306762	325.9888	-0.003	$4s^24p^2$ $^3P_1$	4p7s $^3P_1$	-2.022	5.968E+08
21	326.165[a]	306593	326.165	0	$4s^24p^2$ $^3P_1$	4p7s $^3P_0$	-1.777	1.047E+09
32	326.208[a]	306553	326.2037	0.004	$4s^24p^2$ $^3P_0$	4p6d $^3D_1$	-1.544	1.87E+09
14	329.049[a]	303906	329.0495	-0.001	$4s^24p^2$ $^3P_1$	4p6d $^3P_2$	-2.569	1.658E+08
19	329.196[a]	303770	329.1983	-0.002	$4s^24p^2$ $^3P_2$	4p7s $^3P_1$	-1.632	1.437E+09
8	329.29[a]	303684	329.291	-0.001	$4s^24p^2$ $^3P_1$	4p6d $^3F_2$	-2.569	1.658E+08
22	331.09[a]	302033	331.094	-0.004	$4s^24p^2$ $^3P_2$	4p6d $^3F_3$	-1.205	3.778E+09
7	332.569[a]	300689	332.567	0.002	$4s^24p^2$ $^3P_2$	4p6d $^3F_2$	-2.324	2.861E+08
26	333.891[a]	299499	333.8958	-0.005	$4s^24p^2$ $^1D_2$	4p7s $^1P_1$	-1.197	3.797E+09
14	334.245[a]	299182	334.2466	-0.002	$4s^24p^2$ $^1D_2$	4p7s $^3P_2$	-2.546	1.695E+08
33	335.06[a]	298454	335.0565	0.003	$4s^24p^2$ $^1D_2$	4p6d $^1F_3$	-0.767	1.016E+10
5	336.518[a]	297161	336.5146	0.003	$4s^24p^2$ $^1D_2$	4p6d $^3D_3$	-2.057	5.136E+08
6	337.342[a]	296435	337.3363	0.006	$4s^24p^2$ $^1D_2$	4p6d $^1D_2$	-2.476	1.956E+08
12	341.084[a]	293183	341.0741	0.01	$4s^24p^2$ $^1D_2$	4p7s $^3P_1$	-1.858	7.946E+08
11	343.114[a]	291448	343.11	0.004	$4s^24p^2$ $^1D_2$	4p6d $^3F_3$	-1.608	1.392E+09
15	354.473[a]	282109	354.4698	0.003	$4s^24p^2$ $^1S_0$	4p7s $^1P_1$	-1.595	1.349E+09
14	355.802[a]	281055	355.802	0	$4s^24p^2$ $^1S_0$	4p6d $^1P_1$	-1.734	9.712E+08
10	366.593[a]	272782	366.5961	-0.003	$4s^24p^2$ $^3P_1$	4p6s $^3P_2$	-1.265	2.694E+09
10	369.421[a]	270694	369.4234	-0.002	$4s^24p^2$ $^3P_1$	4p5d $^3P_0$	-1.439	1.781E+09
8	369.961[a]	270299	369.9603	0.001	$4s^24p^2$ $^3P_1$	4p5d $^3P_1$	-1.047	4.377E+09
20	370.661[a]	269788	370.6599	0.001	$4s^24p^2$ $^3P_2$	4p6s $^3P_2$	-0.939	5.585E+09
19	370.588[a]	269841	370.5854	0.003	$4s^24p^2$ $^3P_1$	4p5d $^3P_2$	-2.084	4.0E+08
10	370.923[a]	269598	370.9235	0	$4s^24p^2$ $^3P_0$	4p6s $^3P_1$	-1.397	1.945E+09
40	373.296[a]	267884	373.2983	-0.002	$4s^24p^2$ $^3P_1$	4p5d $^1D_2$	-0.870	6.46E+09
10	374.094[a]	267312	374.0994	-0.005	$4s^24p^2$ $^3P_2$	4p5d $^3P_1$	-1.315	2.312E+09
30	374.497[a]	267025	374.4962	0.001	$4s^24p^2$ $^3P_0$	4p5d $^3D_1$	-0.712	9.224E+09
10	374.571[a]	266972	374.5714	0	$4s^24p^2$ $^3P_1$	4p6s $^3P_1$	-1.465	1.628E+09
40	374.738[a]	266853	374.7387	-0.001	$4s^24p^2$ $^3P_2$	4p5d $^3P_2$	-0.573	1.27E+10
20	375.024[a]	266650	375.0236	0	$4s^24p^2$ $^3P_1$	4p6s $^3P_0$	-1.27	2.549E+09
50	376.33[a]	265724	376.3336	-0.004	$4s^24p^2$ $^3P_2$	4p5d $^3D_3$	-0.358	2.067E+10
15	377.51[a]	264894	377.5129	-0.003	$4s^24p^2$ $^3P_2$	4p5d $^1D_2$	-1.549	1.324E+09
10	378.215[a]	264400	378.2151	0	$4s^24p^2$ $^3P_1$	4p5d $^3D_1$	-1.304	2.313E+09
50	378.811[a]	263984	378.815	-0.004	$4s^24p^2$ $^3P_2$	4p6s $^3P_1$	-1.104	3.657E+09

60	379.675[a]	263383	379.6774	-0.002	$4s^24p^2$	$^3P_1$	4p5d	$^3D_2$	-0.606	1.147E+10
40	383.475[a]	260773	383.4744	0.001	$4s^24p^2$	$^1D_2$	4p5d	$^1P_1$	-1.224	2.699E+09
45	384.033[a]	260394	384.0382	-0.005	$4s^24p^2$	$^3P_2$	4p5d	$^3D_2$	-2.182	2.974E+08
50	384.103[a]	260347	384.1054	-0.002	$4s^24p^2$	$^3P_2$	4p5d	$^3F_3$	-0.71	8.821E+09
60	385.38[a]	259484	385.3805	-0.001	$4s^24p^2$	$^1D_2$	4p6s	$^1P_1$	-0.87	6.062E+09
5	385.78[a]	259215	385.7843	-0.004	$4s^24p^2$	$^1D_2$	4p6s	$^3P_2$	-2.312	2.182E+08
90	386.049[a]	259034	386.0451	0.004	$4s^24p^2$	$^1D_2$	4p5d	$^1F_3$	-0.145	3.205E+10
20	386.582[a]	258677	386.5832	-0.001	$4s^24p^2$	$^3P_2$	4p5d	$^3F_2$	-1.640	1.024E+09
12	390.203	256277	390.2048	-0.002	$4s^24p^2$	$^1D_2$	4p5d	$^3P_2$	-1.23	2.577E+09
5	391.927[a]	255150	391.9343	-0.007	$4s^24p^2$	$^1D_2$	4p5d	$^3D_3$	-2.044	3.918E+08
60	393.214[a]	254314	393.2136	0.001	$4s^24p^2$	$^1D_2$	4p5d	$^1D_2$	-1.089	3.516E+09
40	394.625[a]	253405	394.6265	-0.001	$4s^24p^2$	$^1D_2$	4p6s	$^3P_1$	-1.423	1.616E+09
50	400.297[a]	249815	400.298	-0.001	$4s^24p^2$	$^1D_2$	4p5d	$^3D_2$	-1.293	2.119E+09
40	400.372[a]	249768	400.3711	0.001	$4s^24p^2$	$^1D_2$	4p5d	$^3F_3$	-1.442	1.503E+09
50	403.063[a]	248100	403.0639	-0.001	$4s^24p^2$	$^1D_2$	4p5d	$^3F_2$	-1.367	1.765E+09
80	410.86[a]	243392	410.8624	-0.002	$4s^24p^2$	$^1S_0$	4p5d	$^1P_1$	-0.542	1.130E+10
30	413.049[a]	242102	413.0513	-0.002	$4s^24p^2$	$^1S_0$	4p6s	$^1P_1$	-2.353	1.739E+08
2	417.798	239350	417.8006	-0.003	$4s^24p^2$	$^1S_0$	4p5d	$^3P_1$	-2.865	5.218E+07
20	423.703[a]	236014	423.6909	0.012	$4s^24p^2$	$^1S_0$	4p6s	$^3P_1$	-2.104	2.928E+08
30	428.359[a]	233449	428.3589	0	$4s^24p^2$	$^1S_0$	4p5d	$^3D_1$	-2.039	3.317E+08
100	499.41	200236	499.4072	0.003	$4s4p^3$	$^3D_3$	4p5f	$^3G_4$	-0.852	3.76E+09
40	506.1[a]	197589	506.0957	0.004	$4s^24p^2$	$^3P_1$	4p4d	$^1P_1$	-2.478	8.648E+07
60	511.917	195344	511.912	0.005	$4s4p^3$	$^3D_3$	4p5f	$^3F_4$	-0.695	5.139E+09
10	513.87[a]	194602	513.8736	-0.004	$4s^24p^2$	$^3P_2$	4p4d	$^1P_1$	-3.010	2.461E+07
10	534.457[a]	187106	534.457	0	$4s^24p^2$	$^3P_0$	4p5s	$^1P_1$	-2.475	7.827E+07
85	535.78[a]	186644	535.7816	-0.002	$4s^24p^2$	$^3P_2$	4p4d	$^1F_3$	-0.842	3.356E+09
70	537.619	186005	537.6252	-0.006	$4s4p^3$	$^3D_3$	$4s4p^24d$	$^3F_4$	0.716	1.2E+11
80	542.066[a]	184479	542.0636	0.002	$4s^24p^2$	$^3P_1$	4p5s	$^1P_1$	-1.403	8.987E+08
40	543.411[a]	184023	543.4089	0.002	$4s^24p^2$	$^1D_2$	4p4d	$^1P_1$	-2.687	4.629E+07
95	545.442[a]	183338	545.443	-0.001	$4s^24p^2$	$^3P_1$	4p5s	$^3P_2$	-0.557	6.215E+09
75	545.56	183298	545.548	0.012	$4s4p^3$	$^3P_1$	4p5f	$^3D_2$	-0.864	3.069E+09
100	547.904	182514	547.902	0.002	$4s4p^3$	$^3D_3$	$4s4p^24d$	$^1G_4$	0.258	4.041E+10
95	547.983	182487	547.989	-0.006	$4s4p^3$	$^3D_1$	$4s4p^24d$	$^3D_1$	0.151	3.128E+10
62	548.338	182369	548.338	0	$4s4p^3$	$^3D_2$	$4s4p^24d$	$^3D_1$	-0.312	1.078E+10
100	549.745	181903	549.748	-0.003	$4s4p^3$	$^3D_3$	$4s4p^24d$<2>	$^3D_3$	0.510	7.165E+10
90	549.903[a]	181850	549.905	-0.002	$4s^24p^2$	$^3P_0$	4p5s	$^3P_1$	-0.636	5.086E+09
20	550.992[a]	181491	550.9961	-0.004	$4s^24p^2$	$^3P_2$	4p5s	$^1P_1$	-2.312	1.072E+08
90	553.162	180779	553.166	-0.004	$4s4p^3$	$^3P_2$	4p5f	$^3F_3$	-0.007	2.153E+10
60	554.374	180384	554.3772	-0.003	$4s4p^3$	$^3D_2$	$4s4p^24d$	$^1F_3$	-0.953	2.402E+09
100	554.486[a]	180347	554.4882	-0.002	$4s^24p^2$	$^3P_2$	4p5s	$^3P_2$	-0.386	8.92E+09
70	555.704[a]	179952	555.6985	0.006	$4s^24p^2$	$^3P_0$	4p4d	$^3D_1$	-1.573	5.776E+08
70	555.909[a]	179886	555.9107	-0.002	$4s^24p^2$	$^3P_1$	4p4d	$^1D_2$	-1.371	9.229E+08
60	556.981	179539	556.9836	-0.003	$4s4p^3$	$^3D_3$	$4s4p^24d$	$^1F_3$	-0.802	3.376E+09
90	557.365	179416	557.365	0	$4s4p^3$	$^5S_2$	$4s4p^24d$	$^5P_1$	0.551	7.609E+10
100	557.965[a]	179223	557.961	0.004	$4s^24p^2$	$^3P_1$	4p5s	$^3P_1$	-0.274	1.14E+10
95	559.519[a]	178725	559.525	-0.006	$4s^24p^2$	$^3P_1$	4p5s	$^3P_0$	-1.3	1.066E+09

100	559.756[a]	178649	559.7546	0.001	$4s^24p^2$	$^3P_1$	4p4d	$^3D_2$	0.351	4.774E+10
90	560.59	178383	560.59	0	$4s4p^3$	$^5S_2$	$4s4p^24d$	$^5P_2$	0.742	1.174E+11
63	562.049	177920	562.05	-0.001	$4s4p^3$	$^3P_2$	4p5f	$^3D_3$	-0.157	1.467E+10
73	562.375	177817	562.376	-0.001	$4s4p^3$	$^5S_2$	$4s4p^24d$	$^5P_3$	0.851	1.49E+11
100	563.808[a]	177365	563.8056	0.002	$4s^24p^2$	$^3P_0$	4p4d	$^3P_1$	0.478	6.301E+10
100	563.934[a,B]	177326	563.9264	0.008	$4s^24p^2$	$^3P_1$	4p4d	$^3D_1$	0.264	3.856E+10
95	565.312[a]	176893	565.3093	0.003	$4s^24p^2$	$^3P_2$	4p4d	$^1D_2$	-0.968	2.258E+09
90	567.429[a]	176234	567.4297	-0.001	$4s^24p^2$	$^3P_2$	4p5s	$^3P_1$	-1.04	1.887E+09
90	567.81[a]	176115	567.807	0.003	$4s^24p^2$	$^3P_1$	4p4d	$^3P_0$	0.046	2.305E+10
110	567.971[a]	176065	567.9679	0.003	$4s^24p^2$	$^1D_2$	4p4d	$^1F_3$	0.946	1.830E+11
120	569.162[a]	175697	569.1649	-0.003	$4s^24p^2$	$^3P_2$	4p4d	$^3D_3$	0.947	1.818E+11
100	569.285[a]	175659	569.2848	0	$4s^24p^2$	$^3P_2$	4p4d	$^3D_2$	0.611	8.416E+10
70	569.713	175527	569.713	0	$4s4p^3$	$^3P_1$	$4s4p^24d$	$^3S_1$	-0.054	1.813E+10
60	570.234	175367	570.233	0.001	$4s4p^3$	$^3P_2$	$4s4p^24d$	$^3S_1$	-0.064	1.771E+10
90	572.279[a]	174740	572.2772	0.002	$4s^24p^2$	$^3P_1$	4p4d	$^3P_1$	-1.217	1.235E+09
90	573.472	174376	573.474	-0.002	$4s4p^3$	$^1D_2$	4p5f	$^3G_3$	-0.45	7.206E+09
95	573.603[a]	174337	573.6004	0.003	$4s^24p^2$	$^3P_2$	4p4d	$^3D_1$	0.048	2.269E+10
100	576.596[a]	173432	576.5955	0	$4s^24p^2$	$^3P_1$	4p4d	$^3P_2$	0.572	7.482E+10
70	582.098	171792.4	582.106	-0.008	$4s4p^3$	$^1D_2$	4p5f	$^1F_3$	-0.538	5.759E+09
100	582.245[a]	171749	582.2423	0.003	$4s^24p^2$	$^3P_2$	4p4d	$^3P_1$	-0.363	8.530E+09
100	585.094[a]	170912.7	585.0944	0	$4s^24p^2$	$^1D_2$	4p5s	$^1P_1$	0.119	2.561E+10
100	586.713[a]	170441.1	586.7129	0	$4s^24p^2$	$^3P_2$	4p4d	$^3P_2$	0.148	2.722E+10
46	587.005	170356.3	587.017	-0.012	$4s4p^3$	$^1D_2$	$4s4p^25s$	$^3D_3$	-0.316	9.403E+09
40	589.035[a]	169769.2	589.0336	0.001	$4s^24p^2$	$^1D_2$	4p5s	$^3P_2$	-2.715	3.698E+07
40	589.648	169592.7	589.651	-0.003	$4s4p^3$	$^3D_2$	$4s4p^24d$	$^3D_3$	-0.093	1.547E+10
24	591.659	169016.3	591.661	-0.002	$4s4p^3$	$^3D_1$	$4s4p^24d$	$^3D_2$	-0.339	8.72E+09
68	592.603	168747	592.6	0.003	$4s4p^3$	$^3D_3$	$4s4p^24d$	$^3D_3$	-0.093	1.547E+10
75	595.043	168055.1	595.041	0.002	$4s4p^3$	$^3D_3$	$4s4p^24d$	$^3D_2$	-0.090	1.533E+10
95	597.518[a]	167359	597.5222	-0.004	$4s^24p^2$	$^3P_0$	$4s4p^3$	$^1P_1$	-0.981	1.960E+09
100	600.089[a]	166641.9	600.0946	-0.006	$4s^24p^2$	$^1S_0$	4p4d	$^1P_1$	0.578	6.990E+10
85	601.175	166340.9	601.169	0.006	$4s4p^3$	$^3P_0$	$4s4p^24d$	$^3D_1$	-0.101	1.461E+10
80	601.178	166340.1	601.185	-0.007	$4s4p^3$	$^3P_2$	$4s4p^24d$<2>	$^3D_3$	0.430	5.005E+10
125	601.255[a]	166319	601.26	-0.005	$4s^24p^2$	$^1D_2$	4p4d	$^1D_2$	0.795	1.154E+11
40	601.966	166122.3	601.967	-0.001	$4s4p^3$	$^3P_1$	$4s4p^24d$	$^3D_1$	-0.466	6.295E+09
85	603.663[a]	165655.3	603.6591	0.004	$4s^24p^2$	$^1D_2$	4p5s	$^3P_1$	-0.509	5.65E+09
80	605.625[a]	165118.7	605.6235	0.002	$4s^24p^2$	$^1D_2$	4p4d	$^3D_3$	-0.867	2.46E+09
90	605.764[a]	165080.8	605.7592	0.005	$4s^24p^2$	$^1D_2$	4p4d	$^3D_2$	-1.376	7.644E+08
95	607.04[a]	164733.8	607.0459	-0.006	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^1P_1$	-0.632	4.245E+09
60	607.948	164487.8	607.95	-0.002	$4s4p^3$	$^1D_2$	$4s4p^24d$	$^3S_1$	-0.212	1.108E+10
63	609.853	163973.9	609.849	0.004	$4s4p^3$	$^3P_2$	$4s4p^24d$	$^1F_3$	-0.406	7.047E+09
65	610.648[a]	163760.5	610.6479	0	$4s^24p^2$	$^1D_2$	4p4d	$^3D_1$	-1.694	3.618E+08
40	612.486	163269	612.483	0.003	$4s4p^3$	$^3D_1$	$4p^4$	$^1S_0$	-0.952	1.979E+09
90	618.264[a]	161743.2	618.2705	-0.007	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^1P_1$	-1.342	7.975E+08
90	619.879[a]	161321.8	619.896	-0.017	$4s^24p^2$	$^3P_0$	$4s4p^3$	$^3S_1$	-0.347	7.776E+09
65	620.455[a]	161172	620.4517	0.003	$4s^24p^2$	$^1D_2$	4p4d	$^3P_1$	-1.166	1.179E+09
50	625.375	159904.1	625.3764	-0.001	$4s4p^3$	$^3D_1$	4p4f	$^1D_2$	-1.205	1.065E+09

90	625.526[a]	159865.5	625.5309	-0.005	$4s^24p^2$	$^1D_2$	4p4d	$^3P_2$	-0.695	3.430E+09
5	625.821	159790.1	625.8308	-0.01	$4s4p^3$	$^3D_2$	4p4f	$^1D_2$	-1.424	6.43E+08
3	628.061	159220.2	628.057	0.004	$4s4p^3$	$^3D_3$	4p4f	$^1G_4$	-1.568	4.573E+08
75	630.135[a]	158696.2	630.1519	-0.017	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^3S_1$	0.088	2.050E+10
45	631.378	158383.7	631.3821	-0.004	$4s4p^3$	$^3D_1$	4p4f	$^3D_1$	-1.086	1.363E+09
90	631.84	158267.9	631.8453	-0.005	$4s4p^3$	$^3D_2$	4p4f	$^3D_1$	-1.533	4.863E+08
70	636.285	157162.3	636.2813	0.004	$4s4p^3$	$^3D_2$	4p4f	$^3D_2$	-0.751	2.906E+09
65	637.54	156852.9	637.532	0.008	4p4d	$^3F_3$	4p5f	$^1G_4$	-0.395	6.605E+09
35	639.726	156316.9	639.7171	0.009	$4s4p^3$	$^3D_3$	4p4f	$^3D_2$	-1.373	6.878E+08
90	642.239[a]	155705.3	642.2558	-0.017	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^3S_1$	0.346	3.582E+10
72	642.839	155559.9	642.8437	-0.005	$4s4p^3$	$^3D_3$	4p4f	$^3D_3$	-0.377	6.75E+09
30	644.171	155238.3	644.169	0.002	4p4d	$^3F_2$	4p5f	$^3G_3$	-0.017	1.543E+10
80	645.167[a]	154998.6	645.1713	-0.004	$4s^24p^2$	$^3P_1$	4p4d	$^3F_2$	-1.767	2.745E+08
65	647.569	154423.7	647.567	0.002	4p4d	$^3F_2$	4p5f	$^3D_1$	-0.363	6.885E+09
25	648.241	154263.6	648.233	0.008	4p4d	$^3F_2$	$4s4p^25s$	$^3D_2$	-0.478	5.271E+09
80	649.757[a]	153903.7	649.7595	-0.002	$4s^24p^2$	$^3P_2$	4p4d	$^3F_3$	-1.173	1.063E+09
70.	649.954	153857	649.954	0	4p4d	$^3F_3$	4p5f	$^1D_2$	-0.443	5.689E+09
70	651.335[a]	153530.8	651.3406	-0.006	$4s^24p^2$	$^1S_0$	4p5s	$^1P_1$	-1.018	1.517E+09
24	652.435	153272	652.43	0.005	4p4d	$^3F_2$	$4s4p^25s$	$^3D_1$	-0.393	6.306E+09
70	653.187	153095.5	653.187	0	$4s4p^3$	$^1D_2$	$4s4p^24d$	$^1F_3$	0.522	5.197E+10
63	653.361	153054.7	653.361	0	4p4d	$^3F_4$	4p5f	$^3G_5$	0.391	3.842E+10
80	654.602	152764.6	654.6049	-0.003	$4s4p^3$	$^3D_2$	4p4f	$^1F_3$	-0.297	7.88E+09
80	654.617	152761.1	654.616	0.001	4p4d	$^3F_3$	4p5f	$^3G_4$	0.237	2.69E+10
90	654.906	152693.7	654.9102	-0.004	$4s4p^3$	$^3D_3$	4p4f	$^3F_4$	0.145	2.178E+10
20	655.096	152649.4	655.081	0.015	4p4d	$^3F_2$	4p5f	$^1F_3$	-0.513	4.797E+09
33	656.301	152369.1	656.3	0.001	4p4d	$^3F_3$	$4s4p^25s$	$^3D_2$	-0.081	1.282E+10
75	657.856[a]	152009	657.8649	-0.009	$4s^24p^2$	$^3P_2$	4p4d	$^3F_2$	-1.956	1.708E+08
40	658.554	151847.8	658.557	-0.003	$4s4p^3$	$^3D_3$	$4s4p^24d$<2>	$^3F_4$	-0.45	5.500E+09
10	661.316	151213.6	661.307	0.009	4p4d	$^3F_2$	$4s4p^25s$	$^3D_3$	-1.184	1.002E+09
90	661.523[a]	151166.3	661.5305	-0.008	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^1P_1$	0.228	2.584E+10
75	665.437	150277.2	665.4281	0.009	$4s4p^3$	$^3D_1$	$4s4p^24d$	$^3F_2$	-1.727	2.803E+08
68	665.947	150162.1	665.9426	0.004	$4s4p^3$	$^3D_2$	$4s4p^24d$	$^3F_2$	-1.876	1.988E+08
52	669.778	149303.2	669.77	0.008	$4s4p^3$	$^3D_1$	4p4f	$^3F_2$	0.084	1.803E+10
15	670.283	149190.7	670.291	-0.008	$4s4p^3$	$^3D_2$	4p4f	$^3F_2$	-0.845	2.119E+09
70	671.361	148951.2	671.372	-0.011	$4s4p^3$	$^3D_2$	4p4f	$^3F_3$	-0.058	1.286E+10
36	673.807	148410.4	673.809	-0.002	$4s4p^3$	$^3D_3$	4p4f	$^3G_4$	-0.108	1.145E+10
5	674.449[a]	148269.2	674.4303	0.019	$4s^24p^2$	$^1S_0$	4p5s	$^3P_1$	-3.803	2.304E+06
5	674.503	148257.3	674.511	-0.008	$4s4p^3$	$^1D_2$	$4s4p^24d$	$^3G_3$	-0.711	2.86E+09
63	675.183	148108	675.198	-0.015	$4s4p^3$	$^3D_3$	4p4f	$^3F_3$	-1.74	2.653E+08
10	680.703	146906.9	680.706	-0.003	$4s4p^3$	$^3P_1$	$4p^4$	$^1S_0$	-1.215	8.785E+08
80	683.165[a]	146377.5	683.1656	-0.001	$4s^24p^2$	$^1S_0$	4p4d	$^3D_1$	-3.723	2.713E+06
33	689.052[a]	145126.9	689.0645	-0.012	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^3S_1$	-1.504	4.378E+08
35	690.347	144854.7	690.346	0.001	4p4d	$^3F_4$	4p5f	$^3F_4$	0.044	1.551E+10
7	695.468[a]	143788.1	695.4596	0.008	$4s^24p^2$	$^1S_0$	4p4d	$^3P_1$	-3.684	2.854E+06
45	696.665	143541	696.6685	-0.003	$4s4p^3$	$^3P_1$	4p4f	$^1D_2$	-1.122	1.046E+09
75	697.716[a]	143324.8	697.7091	0.007	$4s^24p^2$	$^1D_2$	4p4d	$^3F_3$	-1.904	1.708E+08

67	703.046	142238.2	703.039	0.007	$4s4p^3$	$^3P_0$	$4p4f$	$^3D_1$	-0.713	2.601E+09
63	704.14	142017.2	704.13	0.01	$4s4p^3$	$^3P_1$	$4p4f$	$^3D_1$	-0.757	2.349E+09
13	704.925	141859.1	704.925	0	$4s4p^3$	$^3P_2$	$4p4f$	$^3D_1$	-1.821	2.029E+08
85	707.057[a]	141431.3	707.0636	-0.007	$4s^24p^2$	$^1D_2$	$4p4d$	$^3F_2$	-1.623	3.181E+08
70	709.642	140916.1	709.6431	-0.001	$4s4p^3$	$^3P_1$	$4p4f$	$^3D_2$	-0.457	4.62E+09
80	710.438	140758.2	710.4508	-0.013	$4s4p^3$	$^3P_2$	$4p4f$	$^3D_2$	-0.707	2.597E+09
80	714.31	139995.2	714.3092	0.001	$4s4p^3$	$^3P_2$	$4p4f$	$^3D_3$	-0.219	7.913E+09
10	721.516	138597.1	721.5054	0.011	$4s4p^3$	$^5S_2$	$4p5p$	$^3P_2$	-3.545	3.645E+06
5	733.369	136357	733.3723	-0.003	$4s4p^3$	$^3P_2$	$4p4f$	$^1F_3$	-1.89	1.615E+08
90	736.051[a,B]	135860	736.0486	0.002	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^1D_2$	-2.170	8.309E+07
5	742.552	134670.7	742.562	-0.01	$4s4p^3$	$^3P_2$	$4s4p^24d$	$^3F_3$	-1.501	3.839E+08
45	743.913	134424.3	743.907	0.006	$4p4d$	$^3F_3$	$4s4p^24d$<2>	$^3D_3$	-0.744	2.181E+09
53	746.491	133960.1	746.5	-0.009	$4p4d$	$^3F_2$	$4s4p^24d$	$^1F_3$	-0.787	1.941E+09
85	747.485[a]	133781.9	747.4875	-0.003	$4s^24p^2$	$^1S_0$	$4s4p^3$	$^1P_1$	-0.926	1.424E+09
90	747.631	133755.8	747.6322	-0.001	$4s4p^3$	$^3P_2$	$4s4p^24d$	$^3F_2$	-2.065	1.029E+08
70	752.619[a]	132869.4	752.6159	0.003	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^1D_2$	-2.557	3.258E+07
70	754.711	132501.1	754.7141	-0.003	$4s4p^3$	$^1D_2$	$4p4f$	$^1D_2$	-0.606	2.928E+09
3	757.038	132093.8	757.039	-0.001	$4p4d$	$^3D_1$	$4p5f$	$^3D_1$	-0.90	1.463E+09
18	757.231	132060.1	757.218	0.013	$4p4d$	$^3F_3$	$4s4p^24d$	$^1F_3$	-1.009	1.134E+09
5	757.436	132024.4	757.444	-0.008	$4p4d$	$^3F_4$	$4s4p^24d$	$^1G_4$	-0.127	8.73E+09
50	763.532	130970.3	763.544	-0.012	$4p4d$	$^3D_3$	$4p5f$	$^3G_4$	-0.328	5.404E+09
65	763.681	130944.7	763.6759	0.005	$4s4p^3$	$^3P_2$	$4p4f$	$^3G_3$	-1.088	9.43E+08
20	771.912	129548.4	771.916	-0.004	$4p5s$	$^3P_0$	$4s4p^25s$	$^3D_1$	-0.562	3.062E+09
30	772.385	129469.1	772.384	0.001	$4p4d$	$^3P_2$	$4p5f$	$^3D_3$	-0.291	5.688E+09
75	774.482	129118.6	774.482	0	$4p4d$	$^3F_2$	$4s4p^24d$	$^3G_3$	0.536	3.813E+10
65	774.498	129115.9	774.4986	-0.001	$4s4p^3$	$^1D_2$	$4p4f$	$^3D_3$	-0.787	1.813E+09
37	775.795	128900.0	775.804	-0.009	$4p5s$	$^3P_1$	$4p5f$	$^3D_2$	-0.316	5.37E+09
70	778.923	128382.4	778.919	0.004	$4p4d$	$^3F_3$	$4s4p^24d$	$^3G_4$	0.692	5.372E+10
70	782.825[a]	127742.5	782.833	-0.008	$4s^24p^2$	$^1S_0$	$4s4p^3$	$^3S_1$	-2.071	9.220E+07
100	784.649[a]	127445.5	784.644	0.005	$4s^24p^2$	$^3P_0$	$4s4p^3$	$^3P_1$	-1.103	8.517E+08
80	785.769	127261.9	785.781	0.010	$4s4p^3$	$^3D_1$	$4p^4$	$^3P_0$	-0.896	1.369E+09
10	786.031	127221.4	786.025	0.006	$4p4d$	$^3F_3$	$4s4p^24d$	$^3G_3$	-0.674	2.288E+09
5	786.958	127071.6	786.956	0.002	$4p4d$	$^3D_3$	$4p5f$	$^3F_3$	-0.692	2.196E+09
15	792.727	126146.9	792.722	0.005	$4s4p^3$	$^3D_1$	$4p^4$	$^3P_1$	-1.028	9.934E+08
25	793.163	126077.5	793.165	-0.002	$4p4d$	$^3D_3$	$4p5f$	$^3F_4$	-0.408	4.166E+09
50	793.446	126032.5	793.446	0.005	$4s4p^3$	$^3D_2$	$4p^4$	$^3P_1$	-0.536	3.087E+09
80	795.485	125709.5	795.485	0	$4p4d$	$^3F_4$	$4s4p^24d$	$^3G_5$	0.826	7.081E+10
75	796.963	125476.3	796.9601	0.003	$4s4p^3$	$^1D_2$	$4p4f$	$^1F_3$	-0.441	3.836E+09
92	800.124[a]	124980.6	800.122	0.002	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^3P_2$	-1.280	5.438E+08
100	801.152[a]	124820.3	801.149	0.003	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^3P_1$	-0.973	1.103E+09
30	801.381	124784.6	801.376	0.005	$4p5s$	$^3P_2$	$4p5f$	$^3D_2$	-0.853	1.454E+09
30	801.381	124784.6	801.392	-0.011	$4p5s$	$^1P_1$	$4s4p^25s$	$^3D_2$	-0.967	1.122E+09
90	802.56[a]	124601.3	802.566	-0.006	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^3P_0$	-1.076	8.688E+08
2	804.413	124314.3	804.419	-0.006	$4p5s$	$^3P_2$	$4p5f$	$^1F_3$	-0.439	3.79E+09
80	805.701	124115.5	805.706	-0.005	$4p4d$	$^1F_3$	$4p5f$	$^1G_4$	-0.051	9.098E+09
36	809.47	123537.6	809.473	-0.003	$4s4p^3$	$^3D_2$	$4p^4$	$^3P_2$	-0.956	1.118E+09

55	813.826	122876.4	813.829	-0.003	$4s4p^3$	$^1D_2$	$4s4p^24d$	$^3F_2$	-1.63	2.355E+08
60	815.052	122691.6	815.042	0.01	$4s4p^3$	$^3D_3$	$4p^4$	$^3P_2$	-0.208	6.196E+09
95	817.709[a]	122292.9	817.7083	0.001	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^1D_2$	-0.350	4.432E+09
13	818.761	122135.8	818.76	0.001	$4s4p^3$	$^1D_2$	$4s4p^24d$	$^5P_3$	-1.586	2.576E+08
100	819.736[a]	121990.5	819.737	-0.001	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^3P_2$	-0.492	3.181E+09
95	820.816[a]	121830	820.815	0.001	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^3P_1$	-1.226	5.871E+08
3	825.164	121188	825.166	-0.002	$4s4p^3$	$^3P_2$	$4p^4$	$^1D_2$	-1.54	2.843E+08
85	832.878	120065.6	832.8753	0.003	$4s4p^3$	$^1D_2$	$4p4f$	$^3G_3$	-0.138	7.063E+09
3	833.195	120019.9	833.187	0.008	$4p4d$	$^1F_3$	$4p5f$	$^3G_4$	-0.937	1.109E+09
20	856.635	116735.8	856.648	-0.013	$4p4d$	$^3D_3$	$4s4p^24d$	$^3F_4$	0.219	1.513E+10
37	865.617	115524.5	865.619	-0.002	$4p4d$	$^3P_2$	$4s4p^24d$	$^1F_3$	-0.824	1.329E+09
30	878.78	113794.1	878.788	-0.008	$4s4p^3$	$^3D_3$	$4p5p$	$^1D_2$	-2.066	7.498E+07
10	890.249	112328.1	890.244	0.005	$4s4p^3$	$^3D_2$	$4p5p$	$^3S_1$	-2.538	2.427E+07
80	897.56[a]	111413.2	897.558	0.002	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^3P_2$	-3.109	6.386E+06
40	898.856[a]	111252.5	898.851	0.005	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^3P_1$	-2.515	2.508E+07
100	900.23[a]	111082.7	900.228	0.002	$4s^24p^2$	$^3P_0$	$4s4p^3$	$^3D_1$	-1.067	7.078E+08
30	901.687	110903.21	901.699	-0.008	$4s4p^3$	$^3P_1$	$4p^4$	$^3P_0$	-1.88	1.086E+08
65	906.44	110321.7	906.444	-0.004	$4s4p^3$	$^3D_1$	$4p5p$	$^3P_2$	-2.544	2.303E+07
50	906.554	110307.8	906.552	0.002	$4s4p^3$	$^1D_2$	$4p^4$	$^1D_2$	-0.059	7.109E+09
68	907.403	110204.6	907.399	0.004	$4s4p^3$	$^3D_2$	$4p5p$	$^3P_2$	-1.511	2.48E+08
80	911.855[w]	109666.6	911.833	0.022	$4s4p^3$	$^3S_1$	$4p4f$	$^1D_2$	-1.392	3.291E+08
95	914.403	109361	914.403	0	$4s4p^3$	$^3D_3$	$4p5p$	$^3P_2$	-0.941	9.117E+08
17	916.212	109145	916.214	-0.002	$4s4p^3$	$^3D_2$	$4p5p$	$^3D_3$	-2.140	5.730E+07
100	921.037[a]	108573.3	921.035	0.002	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^3D_2$	-0.737	1.448E+09
95	922.022[a]	108457.3	922.021	0.001	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^3D_1$	-1.520	2.384E+08
88	922.601	108389.2	922.581	0.02	$4s4p^3$	$^3D_1$	$4p5p$	$^3P_1$	-1.449	2.766E+08
62	923.358	108300.4	923.355	0.003	$4s4p^3$	$^3D_3$	$4p5p$	$^3D_3$	-1.234	4.561E+08
90	923.574	108275	923.57	0.004	$4s4p^3$	$^3D_2$	$4p5p$	$^3P_1$	-1.207	4.824E+08
150	939.61[a]	106427	939.612	0	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^3D_3$	-0.597	1.913E+09
75	940.379	106340.1	940.382	-0.003	$4p4d$	$^3F_2$	$4p4f$	$^1F_3$	-0.175	5.074E+09
70	944.077	105923.6	944.077	0	$4s4p^3$	$^3D_1$	$4p5p$	$^3P_0$	-1.297	3.747E+08
2	945.309	105785.5	945.297	0.012	$4p4d$	$^1F_3$	$4s4p^24d$	$^3F_4$	-0.284	3.873E+09
90	947.118[a]	105583.5	947.124	-0.006	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^3D_2$	-1.898	9.459E+07
75	948.167[a]	105466.7	948.167	0	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^3D_1$	-2.868	1.012E+07
90	950.421	105216.5	950.421	0	$4p4d$	$^3F_3$	$4p4f$	$^3F_4$	-0.022	7.032E+09
40	951.777	105066.6	951.77	0.007	$4p4d$	$^3F_4$	$4p4f$	$^3D_3$	-0.940	8.427E+08
18	954.795	104734.5	954.81	-0.015	$4s4p^3$	$^3D_1$	$4p5p$	$^3D_2$	-2.294	3.703E+07
10	955.54	104652.9	955.546	-0.006	$4p4d$	$^3F_2$	$4s4p^24d$	$^3F_3$	-1.495	2.336E+08
50	955.874	104616.3	955.869	0.005	$4s4p^3$	$^3D_2$	$4p5p$	$^3D_2$	-1.778	1.217E+08
80	957.452	104443.9	957.455	-0.003	$4p4d$	$^3F_3$	$4p4f$	$^1F_3$	-0.744	1.321E+09
90	959.555	104215	959.541	0.014	$4s4p^3$	$^3D_2$	$4p5p$	$^3D_1$	-1.224	4.303E+08
75	963.65	103772.1	963.644	0.006	$4s4p^3$	$^3D_3$	$4p5p$	$^3D_2$	-1.298	3.623E+08
73	963.953	103739.5	963.958	-0.005	$4p4d$	$^3F_2$	$4s4p^24d$	$^3F_2$	-0.629	1.675E+09
70	964.978	103629.3	964.982	-0.004	$4s4p^3$	$^1P_1$	$4p4f$	$^1D_2$	-0.369	3.062E+09
48	973.19	102754.9	973.179	0.011	$4p4d$	$^3F_3$	$4s4p^24d$	$^3F_3$	-0.586	1.829E+09
100	973.859	102684.3	973.859	0	$4p4d$	$^3F_4$	$4p4f$	$^3G_5$	0.55	2.484E+10

25	977.539	102297.7	977.535	0.004	4p4d	$^1F_3$	$4s4p^24d$	$^1G_4$	0.301	1.398E+10
85	978.463	102201.1	978.461	0.002	4p4d	$^3F_4$	4p4f	$^3F_4$	-0.598	1.765E+09
30	986.626	101355.5	986.624	0.002	4p4d	$^3F_4$	$4s4p^24d$<2>	$^3F_4$	-0.352	3.084E+09
35	990.06	101004	990.055	0.005	$4s4p^3$	$^1P_1$	4p4f	$^3D_2$	-1.13	4.984E+08
70	990.77	100931.6	990.749	0.021	4p4d	$^3F_3$	4p4f	$^3G_4$	0.319	1.413E+10
90	990.804	100928.1	990.796	0.008	4p4d	$^3F_2$	4p4f	$^3G_3$	0.106	8.726E+09
70	990.864	100922	990.862	0.002	$4s4p^3$	$^3D_1$	4p5p	$^1P_1$	-1.842	9.721E+07
50	1009.759	99033.5	1009.766	-0.007	4p4d	$^3F_3$	4p4f	$^3G_3$	-1.010	6.438E+08
10	1016.357[b,*]	98390.6	1016.364	-0.007	$4s4p^3$	$^3P_1$	4p5p	$^1D_2$	-2.654	1.453E+07
40	1026.475	97420.8	1026.476	-0.001	4p5p	$^3D_1$	4p6d	$^3D_2$	-2.167	4.342E+07
65	1032.872	96817.4	1032.872	0	4p5p	$^3D_2$	4p6d	$^1D_2$	-1.448	2.248E+08
60	1038.397	96302.3	1038.401	-0.004	$4s4p^3$	$^3P_0$	4p5p	$^3S_1$	-1.527	1.84E+08
5	1038.958	96250.3	1038.961	-0.003	$4s4p^3$	$^1D_2$	$4p^4$	$^3P_2$	-1.815	9.434E+07
90	1040.785	96081.3	1040.783	0.002	$4s4p^3$	$^3P_1$	4p5p	$^3S_1$	-1.148	4.388E+08
90	1042.523	95921.1	1042.521	0.002	$4s4p^3$	$^3P_2$	4p5p	$^3S_1$	-1.252	3.458E+08
120	1043.3[a]	95849.7	1043.297	0.003	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^3D_3$	-1.746	1.096E+08
15	1045.552	95643.3	1045.555	-0.003	4p4d	$^1F_3$	$4s4p^24d$	$^3G_4$	-1.231	3.546E+08
60	1052.573[a]	95005.3	1052.566	0.007	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^3D_2$	-2.820	9.125E+06
90	1053.861[a]	94889.2	1053.854	0.007	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^3D_1$	-2.562	1.651E+07
5	1057.91	94526	1057.91	0	4p5p	$^1P_1$	4p6d	$^3P_2$	-0.796	9.473E+08
45	1063.82[B]	94001	1063.78	0.04	$4s4p^3$	$^1P_1$	$4s4p^24d$	$^3F_2$	-1.996	5.861E+07
50	1064.311[b,*]	93957.5	1064.308	0.003	$4s4p^3$	$^3P_1$	4p5p	$^3P_2$	-1.574	1.57E+08
85	1065.306[a]	93869.7	1065.302	0.004	$4s^24p^2$	$^1S_0$	$4s4p^3$	$^3P_1$	-2.675	1.238E+07
90	1066.128	93797.4	1066.125	0.003	$4s4p^3$	$^3P_2$	4p5p	$^3P_2$	-1.023	5.592E+08
5	1068.733	93568.7	1068.734	-0.001	4p5p	$^3D_2$	4p7s	$^3P_1$	-0.759	1.014E+09
5	1075.092	93015.3	1075.116	-0.024	4p5p	$^3D_3$	4p6d	$^3D_3$	-1.155	3.975E+08
10	1084.014	92249.7	1084.027	-0.013	$4s4p^3$	$^3P_0$	4p5p	$^3P_1$	-2.069	4.82E+07
10	1087.536	91951	1087.513	0.023	4p5p	$^3P_2$	4p6d	$^3D_3$	-0.732	1.03E+09
10	1088.518	91868	1088.518	0	$4s4p^3$	$^3P_2$	4p5p	$^3P_1$	-1.904	7.043E+07
5	1088.784	91845.6	1088.784	0	4p5p	$^3S_1$	4p7s	$^3P_2$	-1.044	5.084E+08
97	1092.358	91545.1	1092.364	-0.006	4p4d	$^3P_2$	4p4f	$^3D_3$	-0.107	4.355E+09
5	1093.709	91432.0	1093.708	0.001	4p5p	$^3P_2$	4p6d	$^3D_2$	-1.082	4.662E+08
75	1098.945	90996.4	1098.947	-0.002	4p4d	$^3P_1$	4p4f	$^3D_2$	-0.486	1.794E+09
55	1102.246	90723.8	1102.244	0.002	4p4d	$^3P_0$	4p4f	$^3D_1$	-0.549	1.535E+09
11	1112.948	89851.5	1112.948	0	4p5p	$^1D_2$	4p7s	$^1P_1$	-0.95	5.964E+08
20	1116.575	89559.6	1116.567	0.008	$4s4p^3$	$^3P_1$	4p5p	$^3P_0$	-1.917	6.479E+07
50	1125.949	88814	1125.949	0	4p5p	$^1D_2$	4p6d	$^1F_3$	-0.675	1.096E+09
32	1131.097	88409.7	1131.112	-0.015	4p4d	$^3D_1$	4p4f	$^3D_2$	-0.668	1.109E+09
25	1133.667	88209.3	1133.667	0	$4s4p^3$	$^3P_2$	4p5p	$^3D_2$	-2.109	4.083E+07
12	1133.907	88190.7	1133.91	-0.003	4p4d	$^3D_2$	4p4f	$^3D_1$	-1.157	3.591E+08
8	1133.929	88188.9	1133.92	0.009	$4s4p^3$	$^3P_0$	4p5p	$^3D_1$	-3.098	4.129E+06
75	1137.588	87905.3	1137.584	0.004	4p4d	$^3P_2$	4p4f	$^1F_3$	-0.884	6.818E+08
70	1138.841	87808.6	1138.835	0.006	$4s4p^3$	$^3P_2$	4p5p	$^3D_1$	-1.595	1.315E+08
90	1144.824	87349.7	1144.818	0.006	$4s4p^3$	$^1D_2$	4p5p	$^1D_2$	-0.969	5.563E+08
95	1148.281	87086.7	1148.277	0.004	4p4d	$^3D_2$	4p4f	$^3D_2$	-0.214	3.076E+09
70	1148.767	87049.9	1148.765	0.002	4p4d	$^3D_3$	4p4f	$^3D_2$	-1.179	3.349E+08

60	1158.4	86326	1158.39	0.01	4p4d	$^3D_2$	4p4f	$^3D_3$	-0.273	2.633E+09
90	1158.881	86290.1	1158.887	-0.006	4p4d	$^3D_3$	4p4f	$^3D_3$	-0.258	2.743E+09
46	1172.279	85303.9	1172.267	0.012	4p4d	$^3P_2$	$4s4p^24d$	$^3F_2$	-1.593	1.232E+08
70	1184.853	84398.7	1184.853	0	$4s4p^3$	$^3P_2$	4p5p	$^1P_1$	-1.669	1.028E+08
22	1189.204	84089.9	1189.195	0.009	4p4d	$^3P_2$	4p4f	$^3F_3$	+0.076	5.593E+09
47	1192.169	83880.7	1192.167	0.002	4p5s	$^1P_1$	4p4f	$^1D_2$	-0.997	4.762E+08
120	1198.701	83423.6	1198.702	-0.001	4p4d	$^3D_3$	4p4f	$^3F_4$	0.26	8.528E+09
115	1209.366	82688	1209.37	-0.004	4p4d	$^3D_2$	4p4f	$^1F_3$	-0.089	3.755E+09
15	1209.923	82649.9	1209.911	0.012	4p4d	$^3D_3$	4p4f	$^1F_3$	-1.06	4.032E+08
35	1212.192	82495.2	1212.198	-0.006	4p4d	$^3P_2$	4p4f	$^3G_3$	-1.025	4.337E+08
38	1224.903	81639.1	1224.902	0.001	4p5s	$^3P_2$	4p4f	$^3D_3$	-0.972	4.71E+08
100	1228.363	81409.2	1228.373	-0.01	4p4d	$^3D_1$	$4s4p^24d$	$^3F_2$	-1.263	2.384E+08
35	1234.746	80988.3	1234.745	0.001	$4s4p^3$	$^1D_2$	4p5p	$^3P_1$	-1.178	2.903E+08
70	1247.209	80179	1247.202	0.007	$4s^24p^2$	$^3P_1$	$4s4p^3$	$^5S_2$	-3.062	3.722E+06
6	1263.56	79141.5	1263.571	-0.011	4p4d	$^3D_3$	4p4f	$^3G_4$	0.067	4.888E+09
100	1265.743	79005	1265.744	-0.001	4p4d	$^1F_3$	4p4f	$^1G_4$	0.723	2.191E+10
5	1290.206[a]	77507	1290.211	-0.005	$4s^24p^2$	$^1S_0$	$4s4p^3$	$^3D_1$	-3.566	1.098E+06
3	1293.161	77329.9	1293.164	-0.003	$4s4p^3$	$^1D_2$	4p5p	$^3D_2$	-2.06	3.505E+07
10	1294.046	77277	1294.048	-0.002	4p4d	$^3D_2$	4p4f	$^3G_3$	-0.902	5.043E+08
10	1294.679	77239.2	1294.668	0.011	4p4d	$^3D_3$	4p4f	$^3G_3$	-1.559	1.117E+08
90	1295.537	77188.1	1295.525	0.012	$4s^24p^2$	$^3P_2$	$4s4p^3$	$^5S_2$	-2.736	7.307E+06
70	1299.895	76929.3	1299.893	0.002	$4s4p^3$	$^1D_2$	4p5p	$^3D_1$	-1.214	2.42E+08
70	1315.061	76042.1	1315.07	-0.009	4p4d	$^1D_2$	4p4f	$^3G_3$	-0.529	1.142E+09
20	1327.273	75342.5	1327.272	0.001	4p4d	$^1F_3$	4p4f	$^3D_3$	-1.395	1.506E+08
40	1360.2	73518.6	1360.192	0.008	$4s4p^3$	$^1D_2$	4p5p	$^1P_1$	-0.602	9.06E+08
65	1394.625	71703.9	1394.632	-0.007	4p4d	$^1F_3$	4p4f	$^1F_3$	-1.131	2.551E+08
85	1413.021	70770.4	1413.028	-0.007	4p4d	$^1P_1$	4p4f	$^1D_2$	0.209	5.503E+09
16	1467.464[D]	68144.8	1467.446	0.018	4p4d	$^1P_1$	4p4f	$^3D_2$	-0.978	3.264E+08
10	1501.222	66612.4	1501.233	-0.011	$4s^24p^2$	$^1D_2$	$4s4p^3$	$^5S_2$	-4.421	1.164E+05
30	1507.909[b]	66317	1507.911	-0.002	4p4d	$^3F_3$	4p5p	$^1D_2$	-1.888	3.861E+07
13	1521.313	65732.7	1521.315	-0.002	$4s4p^3$	$^1P_1$	4p5p	$^1S_0$	-1.564	7.726E+07
73	1539.367	64961.8	1539.372	-0.005	4p5p	$^1P_1$	4p5d	$^1P_1$	-1.253	1.553E+08
82	1567.878	63780.5	1567.865	0.013	4p4d	$^3F_2$	4p5p	$^3P_2$	-1.911	3.305E+07
25	1570.534	63672.6	1570.555	-0.021	4p5p	$^1P_1$	4p6s	$^1P_1$	-0.658	5.97E+08
7	1594.401	62719.5	1594.37	0.031	4p4d	$^3F_2$	4p5p	$^3D_3$	-2.495	8.347E+06
95	1615.89[b]	61885.4	1615.906	-0.01	4p4d	$^3F_3$	4p5p	$^3P_2$	-0.996	2.561E+08
90	1616.765	61851.9	1616.778	-0.013	4p4d	$^3F_2$	4p5p	$^3P_1$	-1.0632	2.187E+08
100	1644.061[b]	60825	1644.074	-0.013	4p4d	$^3F_3$	4p5p	$^3D_3$	-0.896	3.128E+08
90	1659.448	60261	1659.438	0.01	4p5p	$^3D_1$	4p6s	$^1P_1$	-0.569	6.59E+08
70	1667.762	59960.6	1667.773	-0.011	4p5p	$^3P_0$	4p5d	$^1P_1$	-1.550	6.70E+07
15	1709.313	58503	1709.324	-0.011	4p5p	$^1P_1$	4p5d	$^1D_2$	-0.894	2.92E+08
18	1718.427	58192.8	1718.428	-0.001	4p4d	$^3F_2$	4p5p	$^3D_2$	-0.916	2.741E+08
70	1729.822[B]	57809.4	1729.825	-0.003	4p4d	$^3F_4$	4p5p	$^3D_3$	0.256	4.018E+09
90	1730.315[B]	57792.9	1730.33	-0.015	4p4d	$^3F_2$	4p5p	$^3D_1$	-0.366	9.53E+08
76	1736.35	57592.1	1736.347	0.003	4p5p	$^1P_1$	4p6s	$^3P_1$	-0.319	1.059E+09
10	1746.138	57269.2	1746.107	0.031	4p5p	$^1P_1$	4p6s	$^3P_0$	-1.034	2.018E+08

70	1776.31[B]	56296.4	1776.309	0	4p4d	$^3F_3$	4p5p	$^3D_2$	0.057	2.417E+09
67	1779.283[D]	56202.4	1779.283	0	4p5p	$^3P_1$	4p6s	$^1P_1$	-0.227	1.266E+09
5	1787.958	55929.7	1787.924	0.034	4p5p	$^3P_1$	4p6s	$^3P_2$	-1.013	2.037E+08
25	1794.528	55725	1794.549	-0.021	4p4d	$^3P_1$	4p5p	$^1S_0$	-2.262	1.124E+07
66	1815.135	55092.3	1815.137	-0.002	4p5p	$^3D_1$	4p5d	$^1D_2$	-0.647	4.602E+08
100	1816.161	55061.2	1816.151	0.01	4p5p	$^3D_3$	4p6s	$^3P_2$	0.195	3.168E+09
60	1817.524	55019.9	1817.516	0.008	4p5p	$^1P_1$	4p5d	$^3D_1$	-0.311	9.777E+08
37	1828.423	54691.94	1828.421	0.002	4p5p	$^3D_2$	4p5d	$^1D_2$	-0.543	5.709E+08
68	1838.82	54382.7	1838.842	-0.022	4p4d	$^3F_2$	4p5p	$^1P_1$	-0.497	6.268E+08
10	1845.645	54181.6	1845.639	0.006	4p5p	$^3D_1$	4p6s	$^3P_1$	-1.547	5.568E+07
25	1848.48	54098.5	1848.493	-0.013	$4s4p^3$	$^3S_1$	4p5p	$^3D_1$	-2.574	5.242E+06
50	1851.79	54001.8	1851.789	0.001	4p5p	$^1P_1$	4p5d	$^3D_2$	-0.772	3.276E+08
50	1851.791	54001.77	1851.811	-0.02	4p5p	$^3P_2$	4p6s	$^3P_2$	-0.097	1.562E+09
32	1856.665	53860.01	1856.67	-0.005	4p5p	$^3D_1$	4p6s	$^3P_0$	-0.299	9.739E+08
5	1857.221	53843.89	1857.248	-0.027	4p5p	$^3P_1$	4p5d	$^3P_0$	-0.907	2.421E+08
50	1859.377	53781.45	1859.376	0.001	4p5p	$^3D_2$	4p6s	$^3P_1$	-0.028	1.799E+09
15	1870.872	53451.01	1870.897	-0.025	4p5p	$^3P_1$	4p5d	$^3P_1$	-0.474	4.460E+08
67	1881.975	53135.67	1881.938	0.037	4p4d	$^3D_1$	4p5p	$^1S_0$	-1.906	2.306E+07
3	1886.985	52994.59	1886.995	-0.01	4p5p	$^3P_1$	4p5d	$^3P_2$	-1.259	1.042E+08
9	1901.469	52590.92	1901.473	-0.004	4p5p	$^3P_0$	4p6s	$^3P_1$	-0.662	4.034E+08
85	1912.492	52287.8	1912.501	-0.009	4p5p	$^1P_1$	4p5d	$^3F_2$	0.430	4.929E+09
20	1917.578	52149.12	1917.579	-0.001	4p5p	$^3S_1$	4p6s	$^1P_1$	-0.578	4.83E+08
5	1918.479	52124.63	1918.465	0.014	4p5p	$^3D_3$	4p5d	$^3P_2$	-1.193	1.168E+08
40	1927.601	51877.96	1927.618	-0.017	4p5p	$^3S_1$	4p6s	$^3P_2$	-0.099	1.427E+09
25	1940.99	51520.1	1940.967	0.023	4p5p	$^3P_2$	4p5d	$^3P_1$	-0.337	8.236E+08
5	1951.567	51240.87	1951.57	-0.003	4p5s	$^3P_1$	4p5p	$^1S_0$	-1.763	3.012E+07
30	1955.78	51130.5	1955.781	-0.001	4p5p	$^1D_2$	4p5d	$^1P_1$	-0.165	1.15E+09
78	1958.308	51064.49	1958.3	0.008	4p5p	$^3P_2$	4p5d	$^3P_2$	0.307	3.559E+09
90	1959.514	51033.06	1959.505	0.009	4p5p	$^3P_1$	4p5d	$^1D_2$	0.342	3.866E+09
84	1961.021	50993.84	1961.011	0.01	4p5p	$^3D_3$	4p5d	$^3D_3$	0.229	2.943E+09
60	1973.62	50668.32	1973.62	0	4p5p	$^3D_3$	4p5d	$^3F_4$	0.832	1.153E+10
66	1976.612	50591.62	1976.619	-0.007	4p5p	$^3D_1$	4p5d	$^3D_2$	0.434	4.643E+09
140	1993.41[W]	50165.3	1993.461	-0.051	4p5p	$^3D_3$	4p5d	$^1D_2$	-1.244	9.631E+07
150	1994.195	50145.5	1994.193	0.002	4p5p	$^3D_2$	4p5d	$^3F_3$	0.706	8.499E+09
50	1995.096	50122.9	1995.1	-0.004	4p5p	$^3P_1$	4p6s	$^3P_1$	-0.782	2.791E+08
68	1999.239	50019.03	1999.248	-0.009	4p5p	$^3P_0$	4p5d	$^3D_1$	0.086	2.029E+09
	λ_{obs} in Air (Å)		λ_{Ritz} in Air(Å)							
100	2001.997	49933.95	2002.003	-0.006	4p5p	$^3P_2$	4p5d	$^3D_3$	0.531	5.682E+09
16	2005.755	49840.41	2005.744	0.011	4p5p	$^1D_2$	4p6s	$^1P_1$	-0.272	8.713E+08
36	2007.816	49789.26	2007.794	0.022	4p5p	$^3S_1$	4p5d	$^3P_0$	-0.217	1.007E+09
10	2013.473	49649.39	2013.497	-0.024	$4s4p^3$	$^1P_1$	4p5p	$^3P_0$	-2.462	5.561E+06
65	2023.885	49394	2023.885	0	4p5p	$^1D_2$	4p5d	$^1F_3$	0.713	8.225E+09
50	2035.80	49104.9	2035.852	-0.05	4p5p	$^3P_2$	4p5d	$^1D_2$	-0.440	5.913E+08
70	2042.616	48941.11	2042.621	-0.005	4p5p	$^3S_1$	4p5d	$^3P_2$	0.101	2.021E+09
25	2045.306	48876.76	2045.289	0.017	4p5p	$^3D_1$	4p5d	$^3F_2$	-0.272	8.599E+08
25	2062.175	48477	2062.179	-0.005	4p5p	$^3D_2$	4p5d	$^3F_2$	-0.346	7.08E+08

40	2062.482	48469.79	2062.463	0.019	4p4d	$^3P_1$	4p5p	$^1D_2$	-2.086	1.319E+07
40	2080.238	48056.1	2080.164	0.075	$4s4p^3$	$^1P_1$	4p5p	$^3D_1$	-1.76	2.628E+07
75	2102.344	47550.9	2102.347	-0.003	4p5p	$^3P_1$	4p5d	$^3D_1$	-0.452	5.323E+08
60	2143.701	46633.6	2143.748	-0.048	4p5p	$^1D_2$	4p5d	$^3P_2$	-0.624	3.37E+08
70	2148.379	46532.1	2148.36	0.018	4p5p	$^3P_1$	4p5d	$^3D_2$	-0.460	5.041E+08
80	2173.955	45984.7	2173.96	-0.005	4p5s	$^1P_1$	4p5p	$^1S_0$	-0.543	3.992E+08
60	2178.717[b,*]	45884.2	2178.792	-0.075	4p4d	$^3D_1$	4p5p	$^1D_2$	-1.424	5.39E+07
80	2237.893	44671	2237.865	0.028	4p5p	$^1D_2$	4p5d	$^1D_2$	-0.359	5.71E+08
30	2239.069	44647.6	2239.075	-0.006	$4s4p^3$	$^1P_1$	4p5p	$^1P_1$	-1.331	6.113E+07
45	2245.289	44523.9	2245.282	0.006	4p4d	$^3D_3$	4p5p	$^1D_2$	-1.872	1.841E+07
40	2272.727	43986.4	2272.711	0.016	4p5s	$^3P_1$	4p5p	$^1D_2$	-1.028	1.25E+08
80	2278.467	43875.6	2278.426	0.041	4p5p	$^1S_0$	4p5d	$^1P_1$	0.1550	1.826E+09
100	2302.515	43417.4	2302.526	-0.011	4p4d	$^3P_2$	4p5p	$^3P_1$	-0.558	3.46E+08
70	2307.399[b]	43325.5	2307.388	0.011	4p4d	$^1D_2$	4p5p	$^1D_2$	-0.726	2.377E+08

[a] Lines originally classified by Tauheed et al. Ref.[1].
[b] Joshi and Budhiraja Ref.[2], lines above 2000Å were taken from ref. [8]
[*] The designation of the lower level changed.
[c] Intensity figures are visual estimates of photographic blackening.
[d] Observed wavelength value- calculated value from the Table 4.2.
[e] Transition probabilities (gA) obtained by Cowan's code. Here g is the statistical weight of the upper level while for gf, g refers to the weight of the lower level.
[B] Blended with other line, [D] diffuse line, [W] wide line.

Table 4.2: Observed energy levels of Br IV.

Designation[f]		Energy(cm^{-1})	$D_1(cm^{-1})$[c]	$D_2(cm^{-1})$[d]	No. of connecting lines[e]
$4s^24p^2$	$^3P_0$	0[a]	0.6	0	12
$4s^24p^2$	$^3P_1$	2625.6[a]	0.3	0.4	36
$4s^24p^2$	$^3P_2$	5616.3[a]	0.4	0.4	38
$4s^24p^2$	$^1D_2$	16193.1[a]	0.3	0.4	40
$4s^24p^2$	$^1S_0$	33576.3[a]	0.3	0.4	16
$4s4p^3$	$^5S_2$	82805.1	0.3	0.4	5
$4s4p^3$	$^3D_1$	111083.1[a]	0.3	0.4	19
$4s4p^3$	$^3D_2$	111199.1[a]	0.3	0.4	21
$4s4p^3$	$^3D_3$	112043.1[a]	0.3	0.4	22
$4s4p^3$	$^3P_0$	127226.0[a]	0.5	0.5	6
$4s4p^3$	$^3P_1$	127446.3[a]	0.2	0.4	17
$4s4p^3$	$^3P_2$	127606.5[a]	0.2	0.4	22
$4s4p^3$	$^1D_2$	138486.2[a]	0.2	0.4	22
4p4d	$^3F_2$	157623.2[a]	0.3	0.4	21
4p4d	$^3F_3$	159519.4[a]	0.2	0.4	18
$4s4p^3$	$^3S_1$	161317.5[a]	0.4	0.4	7
4p4d	$^3F_4$	162534.6	0.3	0.5	6
$4s4p^3$	$^1P_1$	167357.7[a]	0.4	0.4	12
4p4d	$^3P_2$	176057.4[a]	0.2	0.4	11
4p4d	$^3P_1$	177366.1[a]	0.3	0.4	8
4p4d	$^3P_0$	178741.7[a]	0.4	0.6	2
4p4d	$^3D_1$	179953.7[a]	0.7	0.4	10
4p4d	$^3D_2$	181275.3[a]	0.2	0.4	8
4p4d	$^3D_3$	181312.3[a]	0.2	0.4	13
4p5s	$^3P_0$	181348.4[a]	1.0	1.1	2
4p5s	$^3P_1$	181849.6[a]	0.2	0.4	8
4p4d	$^1D_2$	182510.6[a]	0.2	0.4	5
4p5s	$^3P_2$	185962.8[a]	0.3	0.5	6
4p5s	$^1P_1$	187105.8[a]	0.2	0.4	8
4p4d	$^1F_3$	192259.5[a]	0.2	0.4	10
4p4d	$^1P_1$	200216.6[a]	0.4	0.5	6
4p5p	$^1P_1$	212005.2	0.13	0.4	14
4p5p	$^3D_1$	215415.6	0.13	0.4	14
4p5p	$^3D_2$	215815.9	0.08	0.4	13
4p5p	$^3P_0$	217006.6	0.2	0.4	6
4p5p	$^3P_1$	219474.6	0.2	0.4	16
4p5p	$^3D_3$	220343.9[b]	0.2	0.4	11
4p5p	$^3P_2$	221404.2[b]	0.2	0.4	15
4p5p	$^3S_1$	223527.9	0.2	0.4	9
4p5p	$^1D_2$	225836.3[b]	0.13	0.4	16
4p5p	$^1S_0$	233090.4	0.3	0.4	6
$4p^4$	$^3P_2$	234736.1	0.5	0.5	3

$4p^4$	$^3P_1$	237230.8	0.8	0.7	2
$4p^4$	$^3P_0$	238348.6	1.0	0.6	2
$4p^4$	$^1D_2$	248794.3	0.5	0.6	2
4p4f	$^3G_3$	258552.2	0.2	0.4	8
4p4f	$^3F_3$	260147.8	0.7	0.5	3
4p4f	$^3F_2$	260388.0	1.5	0.9	2
4p4f	$^3G_4$	260453.0	0.8	0.5	3
sp^2d	$^5P_3$	260622.0	0.7	0.8	2
sp^2d	$^5P_2$	261188.5	1.6	1.7	1
sp^2d	$^3F_2$	261362.2	0.4	0.4	8
sp^2d	$^5P_1$	262220.7	1.6	1.7	1
sp^2d	$^3F_3$	262275.4	0.7	0.5	3
sp^2d<2>*	$^3F_4$	263890.3	0.5	0.7	2
4p4f	$^1F_3$	263963.0	0.2	0.4	9
4p5d	$^3F_2$	264292.7[a]	0.2	0.4	5
4p4f	$^3F_4$	264735.9	0.3	0.5	4
4p4f	$^3G_5$	265218.9	0.5	0.7	1
4p5d	$^3F_3$	265961.4[a]	0.3	0.5	3
4p5d	$^3D_2$	266007.1[a]	0.14	0.4	6
4p5d	$^3D_1$	267025.4[a]	0.2	0.4	6
4p4f	$^3D_3$	267601.9	0.2	0.4	9
4p4f	$^3D_2$	268362.3	0.3	0.4	10
4p6s	$^3P_0$	269275.4[a]	0.3	0.4	3
4p4f	$^3D_1$	269465.6	0.3	0.5	7
4p6s	$^3P_1$	269597.4[a]	0.08	0.4	10
4p5d	$^1D_2$	270507.9[a]	0.2	0.4	10
4p4f	$^1D_2$	270986.7	0.3	0.5	8
4p5d	$^3F_4$	271012.2	0.13	0.4	1
4p4f	$^1G_4$	271264.4	0.3	0.5	2
4p5d	$^3D_3$	271337.9[a]	0.2	0.4	4
4p5d	$^3P_2$	272468.9[a]	0.2	0.4	8
4p5d	$^3P_1$	272924.9[a]	0.5	0.4	5
4p5d	$^3P_0$	273317.7[a]	0.5	0.4	3
$4p^4$	$^1S_0$	274352.8	0.9	0.9	2
4p5d	$^1F_3$	275230.3[a]	0.12	0.4	2
4p6s	$^3P_2$	275405.3[a]	0.3	0.4	7
4p6s	$^1P_1$	275676.9[a]	0.2	0.4	7
4p5d	$^1P_1$	276966.8[a]	0.2	0.4	6
sp^2d	$^3D_2$	280098.8	1.1	1.1	2
sp^2d	$^3D_3$	280791.0	1.2	1.1	2
sp^2d	$^3G_3$	286741.8	0.7	0.7	3
sp^2d	$^3G_4$	287902.5	0.5	0.6	2
sp^2d	$^3G_5$	288244.1	0.8	0.9	1
sp^2d	$^1F_3$	291581.6	0.7	0.6	7
sp^2d	$^3D_1$	293568.4	1.0	0.8	4
sp^2d<2>*	$^3D_3$	293944.7	1.0	0.8	3

sp^2d	$^1G_4$	294557.6	0.6	0.6	3
sp^2d	$^3F_4$	298046.4	1.1	0.6	3
sp^2d	$^3S_1$	302973.5	0.9	0.9	3
4p5f	$^3D_3$	305526.6	0.7	0.8	2
4p6d	$^3F_2$	306308.0[a]	3.0	3.0	2
4p6d	$^3P_2$	306531.2[a]	0.4	0.6	2
4p6d	$^3D_1$	306556.9[a]	0.4	0.5	2
4p5f	$^3F_4$	307389.4	0.7	0.7	3
4p6d	$^3F_3$	307645.0[a]	4.0	3.0	2
4p5f	$^3F_3$	308384.2	0.8	0.8	2
sp^2s	$^3D_3$	308839.0	2.0	1.0	2
4p7s	$^3P_0$	309219.0[a]	5.0	5.0	1
4p7s	$^3P_1$	309384.5[a]	0.5	0.6	5
4p5f	$^1F_3$	310276.1	1.3	0.7	3
4p5f	$^3D_2$	310748.2	1.2	0.7	3
sp^2s	$^3D_1$	310896.3	0.9	1.1	2
sp^2s	$^3D_2$	311888.6	1.1	0.8	3
4p5f	$^3D_1$	312047.3	0.7	0.8	2
4p6d	$^3P_0$	312224.0[a]	5.0	5.0	1
4p5f	$^3G_4$	312280.6	1.0	0.6	4
4p6d	$^1D_2$	312633.3[a]	0.5	0.6	4
4p6d	$^3D_2$	312836.3[a]	0.3	0.5	3
4p5f	$^3G_3$	312861.9	1.0	1.0	2
4p6d	$^3P_1$	312961.0[a]	5.0	5.0	1
4p6d	$^3D_3$	313357.1[a]	1.4	0.5	4
4p5f	$^1D_2$	313376.4	1.2	1.3	1
4p6d	$^1P_1$	314633.0[a]	3.0	3.0	2
4p6d	$^1F_3$	314650.2[a]	0.4	0.6	2
4p7s	$^3P_2$	315373.5[a]	0.4	0.6	4
4p5f	$^3G_5$	315589.4	1.2	1.3	1
4p7s	$^1P_1$	315687.8[a]	0.4	0.6	3
4p5f	$^1G_4$	316374.2	1.0	0.8	2

[a] *Levels established by Tauheed et al. Ref. [1]*
[b] Levels established by Joshi and Budhiraja Ref.[2].
[c] uncertainty D_1 is close to the minimum estimated dispersion relative to any other term, [d] Uncertainty of the level value relative to the ground level and both uncertainties were determine by the LOPT code[9].
[e] No. of observed transitions corresponding to each level.
[f] Designation: sp^2d stands for $4s4p^24d$ and sp^2s for $4s4p^25s$.
* $sp^2d<2>{}^3F_4$ stands for $4s4p^24d\ ((^3P)\ ^4P)\ ^3F_4$ and $sp^2d<2>\ ^3D_3$ stands for $4s4p^24d\ ((^1D)\ ^2D)\ ^3D_3$.

Table 4.3: Observed and LSF energy levels of Br IV in cm^{-1}

J	E(obs)	E(LSF)[a]	Diff.[b]	LS-composition[c]
Even Configurations				
0	0.0	11.0	-11.0	$96\%4s^24p^2\,^3P$
	33576.3	33543.0	33.3	$96\%4s^24p^2\,^1S$
	217006.6	216930.0	76.6	$94\%4s^24p5p\,^3P$
	233090.4	232928.0	162.4	$94\%4s^24p5p\,^1S$
	238348.6	238484.0	-135.4	$51\%4p^4\,^3P + 44\%4s4p^24d((^3P)^4P)^3P$
	-	247796.0	-	$99\%4s4p^24d((^3P)^4P)^5D$
	274352.8	274415.0	-62.2	$41\%4p^4\,^1S + 22\%4s4p^24d((^1D)^2D)^1S + 17\%4s4p^24d((^3P)^4P)^3P + 8\%4p^4\,^3P$
	-	277011.0	-	$48\%4s4p^25s((^3P)^4P)^3P + 15\%4p^4\,^1S + 11\%4p^4\,^3P + 7\%4s4p^24d((^3P)^4P)^3P$
	-	279918.0	-	$35\%4s4p^25s((^3P)^4P)^3P + 20\%4s4p^24d((^3P)^4P)^3P + 19\%4p^4\,^3P + 6\%4s4p^24d((^1D)^2D)^3P$
	-	287382.0	-	$78\%4s^24p6p\,^3P + 12\%4s^24p6p\,^1S + 10\%4s4p^25s((^3P)^4P)^3P$
	-	295822.0	-	$86\%4s^24p6p\,^1S + 12\%4s^24p6p\,^3P$
	-	304468.0	-	$88\%4s4p^24d((^1D)^2D)^3P + 9\%4s4p^24d((^3P)^4P)^3P$
	-	330252.0	-	$29\%4s4p^25s((^1S)^2S)^1S + 21\%4s4p^24d((^3P)^2P)^3P + 20\%4s4p^24d((^1D)^2D)^1S + 16\%4s4p^25s((^3P)^2P)^3P$
	-	334649.0	-	$59\%4s4p^24d((^3P)^2P)^3P + 28\%4s4p^25s((^1S)^2S)^1S + 6\%4p^4\,^3P$
	-	335967.0	-	$57\%4s4p^25s((^3P)^2P)^3P + 26\%4s4p^24d((^1D)^2D)^1S + 15\%\,4p^4\,^1S$
	-	341173.0	-	$43\%4s4p^25s((^1S)^2S)^1S + 22\%4s4p^25s((^3P)^2P)^3P + 18\%4s4p^24d((^1D)^2D)^1S + 9\%4p^4\,^1S$
1	2625.6	2611.0	14.6	$98\%4s^24p^2\,^3P$
	212005.2	212081.0	-75.8	$55\%4s^24p5p\,^1P + 41\%4s^24p5p\,^3D$
	215415.7	215342.0	73.7	$46\%4s^24p5p\,^3D + 25\%4s^24p5p\,^1P + 22\%4s^24p5p\,^3P + 6\%4s^24p5p\,^3S$
	219474.6	219343.0	131.6	$66\%4s^24p5p\,^3P + 17\%4s^24p5p\,^1P + 12\%4s^24p5p\,^3D$
	223527.9	223537.0	-9.1	$87\%4s^24p5p\,^3S + 10\%4s^24p5p\,^3P$
	237230.8	237471.0	-240.2	$52\%4p^4\,^3P + 44\%4s4p^24d((^3P)^4P)^3P$
	-	241155.0	-	$98\%4s4p^24d((^3P)^4P)^5F$
	-	247943.0	-	$98\%4s4p^24d((^3P)^4P)^5D$
	262220.7	261911.0	309.7	$97\%4s4p^24d((^3P)^4P)^5P$
	269465.6	269157.0	307.7	$95\%4s^24p4f\,^3D$
	-	269987.0	-	$97\%4s4p^25s((^3P)^4P)^5P$
	-	275454.0	-	$35\%4s4p^24d((^3P)^4P)^3P + 32\%4p^4\,^3P + 11\%4s4p^25s((^3P)^4P)^3P + 9\%4s4p^24d((^3P)^2P)^3P$
	-	279655.0	-	$62\%4s4p^24d((^3P)^4P)^3D + 19\%4s4p^25s((^3P)^4P)^3P + 9\%4s4p^24d((^1S)^2S)^3D$
	-	280404.0	-	$53\%4s4p^25s((^3P)^4P)^3P + 14\%4s4p^24d((^3P)^4P)^3D + 9\%4s^24p6p\,^3P + 7\%4s4p^24d((^3P)^4P)^3P$
	-	284413.0	-	$61\%\,4s^24p6p\,^3D + 33\%4s^24p6p\,^1P$

	-	286481.0	-	27% $4s^24p6p\ ^3P$ +22%$4s^24p6p\ ^1P$ +21%$4s^24p6p\ ^3D$ +20%$4s^24p6p\ ^3S$
	-	290422.0	-	41% $4s^24p6p\ ^1P$ +31%$4s^24p6p\ ^3P$ +14%$4s^24p6p\ ^3D$ +10%$4s^24p6p\ ^3S$
	-	291970.0	-	65% $4s^24p6p\ ^3S$ +30%$4s^24p6p\ ^3P$
	293568.4	293419.0	149.4	90% $4s4p^24d((^1D)^2D)^3D$ +6%$4s4p^24d((^3P)^4P)^3D$
	-	300942.0	-	47% $4s4p^24d((^1D)^2D)^1P$ +30%$4s4p^24d((^3P)^2P)^1P$ +16%$4s4p^24d((^1D)^2D)^3S$
	302973.5	302737.0	236.5	81% $4s4p^24d((^1D)^2D)^3S$ +10%$4s4p^24d((^1D)^2D)^1P$ + 5% $4s4p^24d((^3P)^2P)^1P$
	-	304846.0	-	85% $4s4p^24d((^1D)^2D)^3P$ +10%$4s4p^24d((^3P)4P)^3P$
	-	307340.0	-	40% $4s4p^24d((^1S)^2S)^3D$ +26%$4s4p^25s((^1D)^2D)^3D$ + 21%$4s4p^24d((^3P)^2P)^3D$ +5%$4s4p^24d((^1D)^2D)^1P$
	310896.3	310628.0	268.3	66%$4s4p^25s((^1D)^2D)^3D$ +18%$4s4p^24d((^1S)^2S)^3D$ +6%$4s^24p5f\ ^3D$
	312047.3	312110.0	-62.7	71%$4s^24p5f\ ^3D$ + 22%$4s4p^24d((^3P)^2P)^3D$
	-	324101.0	-	59%$4s4p^24d((^3P)^2P)^1P$ +34%$4s4p^24d((^1D)^2D)^1P$
	-	328554.0	-	46%$4s4p^24d((^3P)^2P)^3D$ +22%$4s4p^24d((^1S)^2S)^3D$ +22%$4s^24p5f\ ^3D$ +6%$4s4p^24d((^3P)^4P)^3D$
	-	329146.0	-	84%$4s4p^25s((^1S)^2S)^3S$ +10%$4s4p^25s((^3P)^2P)^3P$
	-	333484.0	-	76%$4s4p^24d((^3P)^2P)^3P$ + 7%$4s4p^25s((^3P)^2P)^3P$ +7%$4p^4\ ^3P$
	-	338396.0	-	73%$4s4p^25s((^3P)^2P)^3P$ +9%$4s4p^24d((^3P)^2P)^3P$ +9%$4s4p^25s((^1S)^2S)^3S$ +6%$4s4p^25s((^3P)^2P)^1P$
	-	342863.0	-	87%$4s4p^25s((^3P)^2P)^1P$ +8%$4s4p^25s((^3P)^2P)^3P$
2	5616.3	5565.0	51.3	92%$4s^24p^2\ ^3P$ +6%$4s^24p^2\ ^1D$
	16193.1	16278.0	-84.9	92%$4s^24p^2\ ^1D$ +6%$4s^24p^2\ ^3P$
	215815.9	215893.0	-77.1	85%$4s^24p5p\ ^3D$ +9%$4s^24p5p\ ^3P$ +5%$4s^24p5p\ ^1D$
	221404.2	221293.0	111.2	82%$4s^24p5p\ ^3P$ +12%$4s^24p5p\ ^3D$
	225836.3	226269.0	-432.7	90%$4s^24p5p\ ^1D$ +7%$4s^24p5p\ ^3P$
	234736.1	234462.0	274.1	53%$4p^4\ ^3P$ +41%$4s4p^24d((^3P)^4P)^3P$
	-	241740.0	-	96%$4s4p^24d((^3P)^4P)^5F$
	-	248217.0	-	88%$4s4p^24d((^3P)^4P)^5D$ +5%$4p^4\ ^1D$
	248794.3	248637.0	157.3	62% $4p^4\ ^1D$ +25%$4s4p^24d((^1D)^2D)^1D$ +7%$4s4p^24d((^3P)^4P)^5D$
	260388.0	260527.0	-139.0	51%$4s^24p4f\ ^3F$ + 31%$4s4p^24d((^3P)^4P)^3F$ + 7%$4s4p^24d((^1D)^2D)^3F$ +5%$4s^24p4f\ ^3D$
	261188.5	261060.0	128.5	93%$4s4p^24d((^3P)^4P)^5P$
	261362.2	261310.0	52.2	36%$4s4p^24d((^3P)^4P)^3F$ +27%$4s^24p4f\ ^3F$ +24%$4s4p^24d((^1D)^2D)^3F$ +5%$4s4p^24d((^3P)^4P)^5P$
	268362.3	268139.0	223.3	76%$4s^24p4f\ ^3D$ +13%$4s^24p4f\ ^3F$ +7%$4s^24p4f\ ^1D$
	270986.7	271334.0	-347.3	82%$4s^24p4f\ ^1D$ +10%$4s^24p4f\ ^3D$
	-	271975.0	-	96%$4s4p^25s((^3P)^4P)^5P$
	-	273146.0	-	39%$4s4p^24d((^3P)^4P)^3P$ +34%$4p^4\ ^3P$ +9%$4s4p^24d((^3P)^2P)^3P$ +8%$4s4p^24d((^1D)^2D)^3P$
	280098.8	280247.0	-148.2	75%$4s4p^24d((^3P)^4P)^3D$ +10%$4s4p^24d((^1S)^2S)^3D$ +6%$4s4p^24d((^1D)^2D)^3D$

	-	282639.0	-	$76\%4s4p^25s((^3P)4P)^3P + 14\%4s^24p6p\ ^3P$
	-	286481.0	-	$68\%4s^24p6p\ ^3D\ +15\%4s^24p6p\ ^1D$ $+9\%4s4p^25s((^3P)^4P)^3P$
	-	291664.0	-	$45\%4s^24p6p\ ^3P\ +24\%4s^24p6p\ ^1D$ $+ 23\%4s^24p6p\ ^3D +6\%4s4p^25s((^3P)^4P)^3P$
	-	293086.0	-	$59\%4s^24p6p\ ^1D\ +35\%4s^24p6p\ ^3P$
	-	293624.0	-	$81\%4s4p^24d((^1D)^2D)^3D\ +6\%4s4p^24d((^3P)^4P)^3D$ $+ 5\%4s4p^24d((^1D)^2D)^3F$
	-	295080.0	-	$47\%4s4p^24d((^1D)^2D)^3F\ +23\%4s4p^24d((^3P)^4P)^3F$ $+ 19\%4s4p^24d((^3P)^2P)^3F +7\%4s4p^24d((^1D)^2D)^3D$
	-	305076.0	-	$50\%4s^24p5f\ ^3F +18\%4s4p^24d((^3P)^2P)^3F$ $+ 10\%4s^24p5f\ ^3D +7\%4s^24p5f\ ^1D$
	-	305477.0	-	$82\%\ 4s4p^24d((^1D)^2D)^3P\ +11\%4s4p^24d((^3P)^4P)^3P$
	-	307779.0	-	$37\%\ 4s4p^24d((^1S)^2S)^3D\ +35\%4s4p^25s((^1D)^2D)^3D$ $+18\%4s4p^24d((^3P)^2P)^3D$
	310748.2	310795.0	-46.8	$35\%4s4p^25s((^1D)^2D)^3D\ +29\%4s^24p5f\ ^3D$ $+ 20\%4s4p^24d((^1S)^2S)^3D +8\%4s^24p5f\ ^3F$
	311888.6	311743.0	145.6	$24\%4s^24p5f\ ^3D\ +24\%4s4p^25s((^1D)^2D)^3D$ $+ 19\%4s4p^24d((^3P)^2P)^3D + 9\%4s^24p5f\ ^1D$
	313376.4	313320.0	56.4	$38\%4s^24p5f\ ^1D + 17\%4s4p^25s((^1D)^2D)^1D$ $+ 14\%4s^24p5f\ ^3D + 13\%4s4p^24d((^1S)^2S)^1D$
	-	315034.0	-	$61\%4s4p^25s((^1D)^2D)^1D\ +29\%4s^24p5f\ ^1D$
	-	319357.0	-	$36\%4s4p^24d((^1S)^2S)^1D\ +15\%4s4p^25s((^1D)^2D)^1D$ $+ 13\%4s4p^24d((^3P)^2P)^3F +10\%4s^24p5f\ ^3F$
	-	322430.0	-	$31\%\ 4s4p^24d((^3P)^2P)^3F\ +20\%4s^24p5f\ ^3F$ $+17\%4s4p^24d((^1S)^2S)^1D\ +9\%4s4p^24d((^1D)^2D)^1D$
	-	327067.0	-	$48\%4s4p^24d((^1D)^2D)^1D\ +27\%4p^4\ ^1D$ $+12\%4s4p^24d((^1S)^2S)^1D\ +5\%4s4p^24d((^3P)^2P)^3P$
	-	327967.0	-	$44\%4s4p^24d((^3P)^2P)^3D\ +20\%4s^24p5f\ ^3D$ $+19\%4s4p^24d((^1S)^2S)^3D\ +5\%4s4p^24d((^3P)4P)^3D$
	-	332822.0	-	$78\%4s4p^24d((^3P)^2P)^3P + 6\%4p^{4\,3}P$ $+ 4\%4s4p^25s((^3P)^2P)^3P$
	-	340428.0	-	$94\%4s4p^25s((^3P)^2P)^3P$
	-	353291.0	-	$85\%4s4p^24d((^3P)^2P)^1D\ +8\%4s4p^24d((^1S)^2S)^1D$
3	220343.9	220298.0	45.9	$99\%4s^24p5p\ ^3D$
	-	242673.0	-	$95\%4s4p^24d((^3P)^4P)^5F + 5\%4s4p^24d((^3P)^4P)^5D$
	-	248765.0	-	$92\%4s4p^24d((^3P)^4P)^5D + 5\%4s4p^24d((^3P)^4P)^5F$
	258552.2	258946.0	-393.8	$45\%4s^24p4f\ ^3G + 41\%4s^24p4f\ ^1F$ $+ 6\%4s4p^24d((^1D)^2D)^3G$
	260147.8	259885.0	262.8	$41\%4s^24p4f\ ^3F + 15\%4s^24p4f\ ^1F$ $+ 15\%4s^24p4f\ ^3D + 10\%4s4p^24d((^3P)^4P)^5P$
	260622.1	260231.0	391.1	$86\%4s4p^24d\ ((^3P)^4P)^5P + 5\%4s^24p4f\ ^3F$
	262275.4	262398.0	-122.6	$60\%4s4p^24d((^3P)^4P)^3F + 32\%4s4p^24d((^1D)^2D)^3F$
	263963.0	264397.0	-434.0	$31\%4s^24p4f\ ^3G + 29\%4s^24p4f\ ^1F$ $+28\%4s^24p4f\ ^3F\ +5\%4s4p^24d\ ((^1D)^2D)^3G$
	267601.9	267334.0	267.9	$74\%4s^24p4f\ ^3D\ +15\%4s^24p4f\ ^3F$

				+5%4s^{2}4p4f ^{1}F
	-	274664.0	-	99%4s4p^{2}5s((^{3}P)^{4}P)^{5}P
	280791.0	280819.0	-28.0	76%4s4p^{2}4d((^{3}P)^{4}P)^{3}D +10%4s4p^{2}4d((^{1}D)^{2}D)^{3}D +9%4s4p^{2}4d((^{1}S)^{2}S)^{3}D
	286741.8	286755.0	-13.2	78%4s4p^{2}4d((^{1}D)^{2}D)^{3}G +13%4s^{2}4p4f ^{3}G +5%4s^{2}4p5f ^{3}G
	-	290697.0	-	95%4s^{2}4p6p ^{3}D
	291581.6	291252.0	329.6	71%4s4p^{2}4d((^{1}D)^{2}D)^{1}F +10%4s4p^{2}4d((^{3}P)^{2}P)^{1}F +5%4s^{2}4p4f ^{1}F
	293944.7	294309.0	-364.3	74%4s4p^{2}4d((^{1}D)^{2}D)^{3}D +9%4s4p^{2}4d((^{3}P)^{4}P)^{3}D +7%4s4p^{2}4d((^{1}D)^{2}D)^{3}F
	-	296362.0	-	46%4s4p^{2}4d((^{1}D)^{2}D)^{3}F +25%4s4p^{2}4d((^{3}P)^{4}P)^{3}F +15%4s4p^{2}4d((^{3}P)^{2}P)^{3}F +6%4s4p^{2}4d((^{1}D)^{2}D)^{3}D
	305526.6	305107.0	419.6	36%4s^{2}4p5f ^{3}F +26%4s^{2}4p5f ^{3}D +15%4s4p^{2}4d((^{3}P)^{2}P)^{3}F +11%4s4p^{2}4d((^{1}S)^{2}S)^{3}D
	308384.2	308415.0	-30.8	24%4s^{2}4p5f ^{1}F +22%4s^{2}4p5f ^{3}G +18%4s^{2}4p5f ^{3}F +10%4s4p^{2}4d((^{1}S)^{2}S)^{3}D
	308839.0	309111.0	-272.0	57%4s4p^{2}5s((^{1}D)^{2}D)^{3}D +12%4s4p^{2}4d((^{1}S)^{2}S)^{3}D +10%4s^{2}4p5f ^{1}F +8%4s4p^{2}4d((^{3}P)^{2}P)^{3}D
	310276.1	310892.0	-615.9	28%4s^{2}4p5f ^{3}D +15%4s^{2}4p5f ^{3}G +13%4s^{2}4p5f ^{1}F +12%4s^{2}4p5f ^{3}F
	312861.9	312802.0	59.9	40%4s^{2}4p5f ^{3}G +25%4s^{2}4p5f ^{1}F + 12%4s4p^{2}4d((^{1}S)^{2}S)^{3}D +8%4s4p^{2}5s((^{1}D)^{2}D)^{3}D
	-	313419.0	-	21%4s4p^{2}4d((^{3}P)^{2}P)^{3}D +18%4s4p^{2}4d((^{1}S)^{2}S)^{3}D + 15%4s^{2}4p5f ^{3}D +14%4s4p^{2}5s((^{1}D)^{2}D)^{3}D
	-	321481.0	-	40%4s4p^{2}4d((^{3}P)^{2}P)^{3}F +26%4s^{2}4p5f ^{3}F + 15%4s4p^{2}4d((^{3}P)^{2}P)^{3}D +7%4s4p^{2}4d((^{1}D)^{2}D)^{3}F
	-	326831.0	-	44%4s4p^{2}4d((^{3}P)^{2}P)^{3}D +17%4s^{2}4p5f ^{3}D + 12%4s4p^{2}4d((^{1}S)^{2}S)^{3}D +10%4s4p^{2}4d((^{3}P)^{2}P)^{3}F
	-	343408.0	-	80%4s4p^{2}4d((^{3}P)^{2}P)^{1}F +12%4s4p^{2}4d((^{1}D)^{2}D)^{1}F +5%4s^{2}4p5f ^{1}F
4	-	244032.0	-	95%4s4p^{2}4d((^{3}P)4P)^{5}F + 5%4s4p^{2}4d((^{3}P)^{4}P)^{5}D
	-	249682.0	-	94%4s4p^{2}4d((^{3}P)4P)^{5}D + 5%4s4p^{2}4d((^{3}P)^{4}P)^{5}F
	260453.1	260357.0	96.1	45%4s^{2}4p4f ^{3}G + 39%4s^{2}4p4f ^{3}F +7%4s4p^{2}4d((^{1}D)^{2}D)^{3}G + 6%4s^{2}4p4f ^{1}G
	263890.3	264433.0	-542.7	56%4s4p^{2}4d((^{3}P)^{4}P)^{3}F + 33%4s4p^{2}4d((^{1}D)^{2}D)^{3}F + 6%4s^{2}4p4f ^{3}F
	264735.9	264912.0	-176.1	47%4s^{2}4p4f ^{3}F + 36%4s^{2}4p4f ^{3}G + 9%4s4p^{2}4d((^{3}P)^{4}P)^{3}F + 6%4s4p^{2}4d((^{1}D)^{2}D)^{3}G
	271264.4	271355.0	-90.6	91%4s^{2}4p4f ^{1}G
	287902.5	287531.0	371.5	80%4s4p^{2}4d((^{1}D)^{2}D)^{3}G + 15%4s^{2}4p4f ^{3}G +4%4s^{2}4p5f ^{3}G
	294557.6	294924.0	-365.4	66%4s4p^{2}4d((^{1}D)^{2}D)^{1}G + 19%4s4p^{2}4d((^{1}D)^{2}D)^{3}F +7%4s4p^{2}4d((^{3}P)^{4}P)^{3}F + 6%4s4p^{2}4d((^{3}P)^{2}P)^{3}F
	298046.4	298131.0	-84.6	38%4s4p^{2}4d((^{1}D)^{2}D)^{3}F + 30%4s4p^{2}4d((^{1}D)^{2}D)^{1}G + 23%4s4p^{2}4d((^{3}P)^{4}P)^{3}F +6%4s4p^{2}4d((^{3}P)^{2}P)^{3}F
	307389.4	307431.0	-41.6	61%4s^{2}4p5f ^{3}F + 22%4s4p^{2}4d((^{3}P)^{2}P)^{3}F + 7%4s^{2}4p5f ^{3}G + 5%4s^{2}4p5f ^{1}G
	312280.6	312314.0	-33.4	60%4s^{2}4p5f ^{3}G + 22%4s^{2}4p5f ^{1}G

				$+9\%4s4p^24d((^3P)^2P)^3F + 5\%4s^24p5f\,^3F$
	316374.2	316347.0	27.2	$71\%4s^24p5f\,^1G + 27\%4s^24p5f\,^3G$
	-	323252.0	-	$53\%4s4p^24d((^3P)^2P)^3F + 31\%4s^24p5f\,^3F$ $+7\%4s4p^24d((^1D)^2D)^3F$
5	-	245854.0	-	$99\%4s4p^24d((^3P)^4P)^5F$
	265218.9	264991.0	227.9	$83\%4s^24p4f\,^3G + 17\%4s4p^24d((^1D)^2D)^3G$
	288244.1	288313.0	-68.9	$79\%4s4p^24d((^1D)^2D)^3G + 17\%4s^24p4f\,^3G$
	315589.4	315435.0	154.4	$96\%4s^24p5f\,^3G$

odd configurations

0	127226.0	127217.0	9.0	$86\%4s4p^3(^2P)^3P + 12\%4s^24p4d\,^3P$
	178741.7	178948.0	-206.3	$49\%4s^24p4d\,^3P + 42\%4s^24p5s\,^3P$
				$+7\%4s4p^3(^2P)^3P$
	181348.4	181228.0	120.4	$56\%4s^24p5s\,^3P + 37\%4s^24p4d\,^3P$
				$+5\%4s4p^3(^2P)^3P$
	269275.4	269272.0	3.4	$99\%4s^24p6s\,^3P$
	273317.7	273423.0	-105.3	$98\%4s^24p5d\,^3P$
	-	305880.0	-	$98\%4s4p^25p((^3P)4P)^5D$
	309219.0	309218.0	1.0	$100\%4s^24p7s\,^3P$
	312224.0*	313616.0	-	$95\%4s^24p6d\,^3P$
	-	320128.0	-	$91\%4s4p^25p((^3P)4P)^3P$
	-	337161.0	-	$100\%4s^24p8s\,^3P$
	-	342223.0	-	$99\%4s^24p7d\,^3P$
	-	350469.0	-	$91\%4s4p^25p((^1D)^2D)^3P$
	-	357017.0	-	$93\%4s4p^24f((^3P)4P)^5D + 6\%4p^34d(^4S)^5D$
	-	363957.0	-	$66\%4s4p^25p((^1S)^2S)^3P + 16\%4s4p^25p((^3P)^2P)^1S$
				$+10\%4s4p^25p((^3P)^2P)^3P + 6\%4s4p^25p((^1D)^2D)^3P$
	-	368613.0	-	$76\%4s4p^25p((^3P)^2P)^1S + 22\%4s4p^25p((^1S)^2S)^3P$
	-	376292.0	-	$87\%4s4p^25p((^3P)^2P)^3P + 5\%4s4p^25p((^3P)^2P)^1S$
				$+5\%4s4p^25p((^1S)^2S)^3P$
	-	385334.0	-	$67\%4p^34d(^2D)^1S + 32\%4s4p4d^2(^3P,^3P)^1S$
1	111083.1	111361.0	-277.9	$85\%4s4p^3(^2D)^3D + 11\%4s^24p4d\,^3D$
	127446.3	127305.0	141.3	$84\%4s4p^3(^2P)^3P + 12\%4s^24p4d\,^3P$
	161317.5	161081.0	236.5	$81\%4s4p^3(^4S)^3S + 12\%4s4p^3(^2P)^1P$
	167357.7	167740.0	-382.3	$64\%4s4p^3(^2P)^1P + 19\%4s^24p4d\,^1P + 14\%4s4p^3(^4S)^3S$
	177366.1	177345.0	21.1	$43\%4s^24p4d\,^3P + 38\%4s^24p4d\,^3D + 6\%4s4p^3(^2P)^3P +$ $5\%4s4p^3(^2D)^3D$
	179953.7	180114.0	-160.3	$39\%4s^24p5s\,^3P + 29\%4s^24p4d\,^3D$
				$+ 14\%4s^24p4d\,^3P + 9\%4s^24p5s\,^1P$
	181849.6	181708.0	141.6	$36\%4s^24p5s\,^3P + 27\%4s^24p4d\,^3P$
				$+17\%4s^24p4d\,^3D + 11\%4s^24p5s\,^1P$
	187105.8	187134.0	-28.2	$71\%4s^24p5s\,^1P + 20\%4s^24p5s\,^3P$
	200216.6	199939.0	277.6	$71\%4s^24p4d\,^1P + 16\%4s4p^3(^2P)^1P + 7\%4s^24p5s\,^1P$
	267025.4	266854.0	171.4	$76\%4s^24p5d\,^3D + 13\%4s^24p5d\,^3P + 10\%4s^24p5d\,^1P$
	269597.4	269601.0	-3.6	$73\%4s^24p6s\,^3P + 26\%4s^24p6s\,^1P$
	272924.9	273013.0	-88.1	$78\%4s^24p5d\,^3P + 17\%4s^24p5d\,^3D$
	275676.9	275876.0	-199.1	$47\%4s^24p6s\,^1P + 26\%4s^24p5d\,^1P + 20\%4s^24p6s\,^3P$

	276966.8	276633.0	333.8	59%$4s^24p5d\ ^1P$ +25%$4s^24p6s\ ^1P$ +7%$4s^24p6s\ ^3P$
	-	305871.0	-	53%$4s4p^25p((^3P)^4P)^3S$ +34%$4s4p^25p((^3P)^4P)^5D$ +9%$4s4p^25p((^3P)^4P)^5P$
	-	306787.0	-	58%$4s4p^25p((^3P)^4P)^5D$ + 32%$4s4p^25p((^3P)^4P)^3S$ +5%$4s^24p6d\ ^3D$
	306556.9	307104.0	-547.1	58%$4s^24p6d\ ^3D$ +16%$4s^24p6d\ ^1P$ + 13%$4s^24p6d\ ^3P$ +6%$4s4p^25p((^3P)^4P)^5D$
	309384.5	309385.0	-0.5	70%$4s^24p7s\ ^3P$ +30%$4s^24p7s\ ^1P$
	-	311177.0	-	89%$4s4p^25p((^3P)^4P)^5P$ +6%$4s4p^25p((^3P)^4P)^3S$
	312961.0	313149.0	-188.0	57%$4s^24p6d\ ^3P$ +17%$4s4p^25p((^3P)^4P)^3D$ +16%$4s^24p6d\ ^3D$ +8%$4s^24p6d\ ^1P$
	314633.0	314456.0	177.0	38%$4s^24p6d\ ^1P$ +31%$4s4p^25p((^3P)^4P)^3D$ +24%$4s^24p6d\ ^3P$
	-	315647.0	-	39%$4s4p^25p((^3P)^4P)^3D$ +31%$4s^24p6d\ ^1P$ +17%$4s^24p6d\ ^3D$ +6%$4s^24p7s\ ^1P$
	315687.8	315711.0	-23.2	64%$4s^24p7s\ ^1P$ +27%$4s^24p7s\ ^3P$
	-	321088.0	-	87%$4s4p^25p((^3P)^4P)^3P$
	-	336531.0	-	59%$4s^24p7d\ ^3D$ +23%$4s^24p7d\ ^1P$ +16%$4s^24p7d\ ^3P$
	-	337254.0	-	69%$4s^24p8s\ ^3P$ +31%$4s^24p8s\ ^1P$
	-	342010.0	-	64%$4s^24p7d\ ^3P$ +27%$4s^24p7d\ ^3D$
	-	342807.0	-	69% $4s^24p7d\ ^1P$ +19%$4s^24p7d\ ^3P$ +8%$4s^24p7d\ ^3D$
	-	343015.0	-	68%$4s^24p8s\ ^1P$ +30%$4s^24p8s\ ^3P$
	-	344798.0	-	87%$4s4p^25p((^1D)^2D)^3D$ +5%$4s^24p7d\ ^3D$
	-	350452.0	-	84%$4s4p^25p((^1D)^2D)^3P$ +6%$4s4p^25p((^1D)^2D)^1P$
	-	351559.0	-	81%$4s4p^25p((^1D)^2D)^1P$ +7%$4s4p^25p((^1D)^2D)^3P$ +5%$4s4p^25p((^1S)^2S)^1P$
	-	356378.0	-	72%$4s4p^24f((^3P)^4P)^5D$ +15%$4s4p^24f((^3P)4P)^3D$ +7%$4s4p^24f((^3P)^4P)^5F$
	-	357520.0	-	73%$4s4p^24f((^3P)^4P)^3D$ +18%$4s4p^24f((^3P)^4P)^5D$
	-	360730.0	-	91%$4s4p^24f\ ((^3P)^4P)^5F$ +5%$4s4p^24f((^3P)^4P)^3D$
	-	364811.0	-	74%$4s4p^25p((^1S)^2S)^3P$ +9%$4s4p^25p((^3P)^2P)^3D$ +5%$4s4p^25p((^1S)^2S)^1P$
	-	367393.0	-	59%$4s4p^25p((^1S)^2S)^1P$ +14%$4s4p^25p((^3P)^2P)^3D$ + 10%$4s4p^25p((^1S)^2S)^3P$ +7%$4s4p^25p((^3P)^2P)^3P$
	-	372623.0	-	72%$4s4p^25p((^3P)^2P)^3D$ +21%$4s4p^25p((^1S)^2S)^1P$
	-	375298.0	-	70%$4s4p^25p((^3P)^2P)^3S$ +17%$4s4p^25p((^3P)^2P)^3P$ +5%$4s4p^25p((^1S)^2S)^3P$
	-	376940.0	-	71%$4s4p^25p((^3P)^2P)^3P$ +23%$4s4p^25p((^3P)^2P)^3S$
	-	384922.0	-	89%$4s4p^25p((^3P)^2P)^1P$
2	82805.1	82790.0	15.1	99%$4s4p^3(^4S)^5S$
	111199.1	111395.0	-195.9	84%$4s4p^3(^2D)^3D$ +11%$4s^24p4d\ ^3D$
	127606.5	127250.0	356.5	79%$4s4p^3(^2P)^3P$ +12%$4s^24p4d\ ^3P$
	138486.2	138300.0	186.2	47%$4s4p^3(^2D)^1D$ +46%$4s^24p4d\ ^1D$
	157623.2	157720.0	-96.8	97%$4s^24p4d\ ^3F$
	176057.4	175961.0	96.4	60%$4s^24p4d\ ^3P$ +18%$4s^24p4d\ ^3D$ +9%$4s4p^3(^2P)^3P$
	181275.3	181271.0	4.3	67%$4s^24p4d\ ^3D$ +12%$4s^24p4d\ ^3P$ +8%$4s4p^3(^2D)^3D$
	182510.6	182851.0	-340.4	43%$4s^24p4d\ ^1D$ +37%$4s4p^3(^2D)^1D$ +10%$4s^24p4d\ ^3P$
	185962.8	185921.0	41.8	95%$4s^24p5s\ ^3P$
	264292.7	264456.0	-163.3	72%$4s^24p5d\ ^3F$ +24%$4s^24p5d\ ^1D$

	266007.1	265965.0	42.1	38%4s^{2}4p5d ^{3}D +29%4s^{2}4p5d ^{3}P +25%4s^{2}4p5d ^{1}D +6%4s^{2}4p5d ^{3}F
	270507.9	270637.0	-129.1	44%4s^{2}4p5d ^{1}D +29%4s^{2}4p5d ^{3}D +21%4s^{2}4p5d ^{3}F
	272468.9	272538.0	-69.1	64%4s^{2}4p5d ^{3}P +28%4s^{2}4p5d ^{3}D +5%4s^{2}4p5d ^{1}D
	275405.3	275374.0	31.3	98%4s^{2}4p6s ^{3}P
	306308.0	306287.0	51.0	73%4s^{2}4p6d ^{3}F +21%4s^{2}4p6d ^{1}D +5%4s^{2}4p6d ^{3}D
	306531.2	*306654.0*	*-129.8*	*38%4s^{2}4p6d ^{3}D +37%4s^{2}4p6d ^{3}P +18%4s^{2}4p6d ^{1}D*
	-	307568.0	-	90%4s4p^{2}5p((^{3}P)^{4}P)^{5}D +7%4s4p^{2}5p((^{3}P)^{4}P)^{5}P
	-	310703.0	-	49%4s4p^{2}5p((^{3}P)^{4}P)^{5}P +41%4s4p^{2}5p((^{3}P)^{4}P)^{5}S +7%4s4p^{2}5p((^{3}P)^{4}P)^{5}D
	312633.3	312393.0	240.3	40%4s^{2}4p6d ^{1}D +30%4s^{2}4p6d ^{3}D +24%4s^{2}4p6d ^{3}F +5%4s4p^{2}5p((^{3}P)^{4}P)^{3}D
	312836.3	313076.0	-239.7	56%4s^{2}4p6d ^{3}P +20%4s^{2}4p6d ^{1}D +15%4s^{2}4p6d ^{3}D +5%4s4p^{2}5p((^{3}P)^{4}P)^{3}D
	-	313578.0	-	55%4s4p^{2}5p((^{3}P)^{4}P)^{5}S +39%4s4p^{2}5p((^{3}P)^{4}P)^{5}P
	315373.5	315352.0	21.5	99%4s^{2}4p7s ^{3}P
	-	316558.0	-	79%4s4p^{2}5p((^{3}P)^{4}P)^{3}D +10%4s^{2}4p6d ^{3}D +5%4s4p^{2}5p((^{3}P)^{4}P)^{3}P
	-	320392.0	-	100%4s^{2}4p5g ^{3}F
	-	321976.0	-	87%4s4p^{2}5p((^{3}P)^{4}P)^{3}P
	-	335696.0	-	73%4s^{2}4p7d ^{3}F +18%4s^{2}4p7d ^{1}D
	-	336273.0	-	42%4s^{2}4p7d ^{3}P +36%4s^{2}4p7d ^{3}D +18%4s^{2}4p7d ^{1}D
	-	341291.0	-	46%4s^{2}4p7d ^{1}D +29%4s^{2}4p7d ^{3}D +18%4s^{2}4p7d ^{3}F
	-	341885.0	-	55%4s^{2}4p7d ^{3}P +25%4s^{2}4p7d ^{3}D +16%4s^{2}4p7d ^{1}D
	-	342812.0	-	99%4s^{2}4p8s ^{3}P
	-	344926.0	-	31%4s4p^{2}5p((^{1}D)^{2}D)^{1}D +29%4s4p^{2}5p((^{1}D)^{2}D)^{3}D +29%4s4p^{2}5p((^{1}D)^{2}D)^{3}F
	-	345201.0	-	58%4s4p^{2}5p((^{1}D)^{2}D)^{3}D +16%4s4p^{2}5p((^{1}D)^{2}D)^{3}F +15%4s4p^{2}5p((^{1}D)^{2}D)^{1}D
	-	346508.0	-	47%4s4p^{2}5p((^{1}D)^{2}D)^{3}F +45%4s4p^{2}5p((^{1}D)^{2}D)^{1}D
	-	350756.0	-	87%4s4p^{2}5p((^{1}D)^{2}D)^{3}P
	-	354110.0	-	86%4s4p^{2}4f((^{3}P)^{4}P)^{5}G
	-	355524.0	-	53% 4s4p^{2}4f((^{3}P)^{4}P)^{5}D +26% 4s4p^{2}4f((^{3}P)^{4}P)^{3}D +10%4s4p^{2}4f((^{3}P)^{4}P)^{5}G +5%4s4p^{2}4f((^{3}P)^{4}P)^{5}F
	-	356548.0	-	58%4s4p^{2}4f((^{3}P)4P)^{3}D +31%4s4p^{2}4f((^{3}P)^{4}P)^{5}D
	-	360984.0	-	89%4s4p^{2}4f((^{3}P)4P)^{5}F +6%4s4p^{2}4f((^{3}P)^{4}P)^{5}D
	-	362982.0	-	88%4s4p^{2}4f((^{3}P)4P)^{3}F
	-	365599.0	-	82%4s4p^{2}5p((^{1}S)^{2}S)^{3}P + 9%4s4p^{2}5p((^{3}P)^{2}P)^{3}D
	-	373262.0	-	83%4s4p^{2}5p((^{3}P)^{2}P)^{3}D + 10%4s4p^{2}5p((^{1}S)^{2}S)^{3}P
	-	377617.0	-	83%4s4p^{2}5p((^{3}P)^{2}P)^{3}P + 8%4s4p^{2}5p((^{3}P)^{2}P)^{1}D
	-	380155.0	-	84%4s4p^{2}5p((^{3}P)^{2}P)^{1}D + 10%4s4p^{2}5p((^{3}P)^{2}P)^{3}P
	-	384323.0	-	47%4s4p^{2}4f((^{1}D)^{2}D)^{3}F + 31%4p^{3}4d(^{2}D)^{3}F +7%4p^{3}4d(^{2}P)^{3}F
3	112043.1	112036.0	7.1	87%4s4p^3(^{2}D)^{3}D +11%4s^{2}4p4d ^{3}D
	159519.4	159563.0	-43.6	97%4s^{2}4p4d ^{3}F
	181312.3	181070.0	242.3	85%4s^{2}4p4d ^{3}D +10%4s4p^3(^{2}D)^{3}D
	192259.5	192474.0	-214.5	95%4s^{2}4p4d ^{1}F
	265961.4	266003.0	-41.6	67%4s^{2}4p5d ^{3}F +23%4s^{2}4p5d ^{3}D +10%4s^{2}4p5d ^{1}F
	271337.9	271325.0	12.9	71%4s^{2}4p5d ^{3}D +27%4s^{2}4p5d ^{3}F

	275230.3	275286.0	-55.7	88%4s^{2}4p5d ^{1}F +5%4s^{2}4p5d ^{3}F +5%4s^{2}4p5d ^{3}D
	307645.0	307076.0	569.0	52%4s^{2}4p6d ^{3}F +28%4s^{2}4p6d ^{3}D +18%4s^{2}4p6d ^{1}F
	-	309380.0	-	93%4s4p^{2}5p((^{3}P)^{4}P)^{5}D +6%4s4p^{2}5p((^{3}P)^{4}P)^{5}P
	313357.1*	312534.0	-	57% 4s^{2}4p6d ^{3}D +31% 4s^{2}4p6d ^{3}F +7%4s4p^{2}5p((^{3}P)^{4}P)^{3}D
	-	313532.0	-	86% 4s4p^{2}5p((^{3}P)^{4}P)^{5}P + 5%4s4p^{2}5p((^{3}P)^{4}P)^{5}D
	-	314137.0	-	53% 4s^{2}4p5g ^{3}G +26%4s^{2}4p5g ^{1}F +20%4s^{2}4p5g ^{3}F
	314650.2	314608.0	42.2	78% 4s^{2}4p6d ^{1}F + 13%4s^{2}4p6d ^{3}F
	-	319022.0	-	84% 4s4p^{2}5p((^{3}P)^{4}P)^{3}D +7%4s^{2}4p6d ^{3}D +5%4s4p^{2}5p((^{3}P)^{4}P)^{5}P
	-	319741.0	-	46% 4s^{2}4p5g ^{3}G + 27%4s^{2}4p5g ^{1}F +26%4s^{2}4p5g ^{3}F
	-	320435.0	-	53% 4s^{2}4p5g ^{3}F + 46%4s^{2}4p5g ^{1}F
	-	336321.0	-	52% 4s^{2}4p7d ^{3}F + 23%4s^{2}4p7d ^{3}D + 22% 4s^{2}4p7d ^{1}F
	-	341317.0	-	57% 4s^{2}4p7d ^{3}D +30%4s^{2}4p7d ^{3}F +5%4s4p^{2}5p((^{1}D)^{2}D)^{3}D +5%4s4p^{2}5p((^{1}D)^{2}D)^{3}F
	-	342546.0	-	75% 4s^{2}4p7d ^{1}F +12%4s^{2}4p7d ^{3}D +8% 4s^{2}4p7d ^{3}F
	-	345475.0	-	87% 4s4p^{2}5p((^{1}D)^{2}D)^{3}D + 7%4s^{2}4p7d ^{3}D
	-	346466.0	-	86% 4s4p^{2}5p((^{1}D)^{2}D)^{3}F + 9%4s^{2}4p7d ^{3}F
	-	349289.0	-	98% 4s4p^{2}5p((^{1}D)^{2}D)^{1}F
	-	353939.0	-	37% 4s4p^{2}4f((^{3}P)^{4}P)^{3}D +29%4s4p^{2}4f((^{3}P)4P)^{5}D +20% 4s4p^{2}4f((^{3}P)^{4}P)^{5}G +8% 4s4p^{2}4f((^{3}P)^{4}P)^{5}F
	-	354704.0	-	34% 4s4p^{2}4f((^{3}P)^{4}P)^{3}D +20%4s4p^{2}4f((^{3}P)^{4}P)^{3}G
	-	355321.0	-	55% 4s4p^{2}4f((^{3}P)^{4}P)^{5}D +30%4s4p^{2}4f((^{3}P)^{4}P)^{5}G +8% 4s4p^{2}4f((^{3}P)^{4}P)^{3}D
	-	356140.0	-	71% 4s4p^{2}4f((^{3}P)^{4}P)^{3}G +10%4s4p^{2}4f((^{3}P)^{4}P)^{3}D
	-	361361.0	-	88% 4s4p^{2}4f((^{3}P)^{4}P)^{5}F +6%4s4p^{2}4f((^{3}P)^{4}P)^{5}D
	-	363507.0	-	86% 4s4p^{2}4f((^{3}P)^{4}P)^{3}F
	-	375260.0	-	96% 4s4p^{2}5p((^{3}P)^{2}P)^{3}D
	-	384827.0	-	52% 4s4p^{2}4f((^{1}D)^{2}D)^{3}F +29%4p^{3}4d(^{2}D)^{3}F +6%4p^{3}4d(^{2}P)^{3}F
4	162534.6	162482.0	52.6	98%4s^{2}4p4d ^{3}F
	271012.2	270754.0	258.2	99%4s^{2}4p5d ^{3}F
	-	311755.0	-	94%4s4p^{2}5p((^{3}P)4P)^{5}D +5%4s^{2}4p6d ^{3}F
	-	312865.0	-	92%4s^{2}4p6d ^{3}F +5%4s4p^{2}5p((^{3}P)^{4}P)^{5}D
	-	314128.0	-	45%4s^{2}4p5g ^{3}F +28%4s^{2}4p5g ^{1}G +24%4s^{2}4p5g ^{3}G
	-	314162.0	-	64%4s^{2}4p5g ^{3}H +20%4s^{2}4p5g ^{3}G +15%4s^{2}4p5g ^{1}G
	-	319419.0	-	37%4s^{2}4p5g ^{1}G +35%4s^{2}4p5g ^{3}H +28%4s^{2}4p5g ^{3}G
	-	319714.0	-	53%4s^{2}4p5g ^{3}F +27%4s^{2}4p5g ^{3}G +20%4s^{2}4p5g ^{1}G
	-	341126.0	-	89%4s^{2}4p7d ^{3}F + 10%4s4p^{2}5p((^{1}D)^{2}D)^{3}F
	-	347298.0	-	87%4s4p^{2}5p((^{1}D)^{2}D)^{3}F + 11%4s^{2}4p7d ^{3}F
	-	353555.0	-	82% 4s4p^{2}4f((^{3}P)^{4}P)^{5}D + 7%4s4p^{2}4f((^{3}P)^{4}P)^{5}F
	-	355679.0	-	78% 4s4p^{2}4f((^{3}P)^{4}P)^{5}G +9%4s4p^{2}4f((^{3}P)^{4}P)^{3}G +7%4s4p^{2}4f((^{3}P)^{4}P)^{5}D
	-	357559.0	-	79% 4s4p^{2}4f((^{3}P)^{4}P)^{3}G + 10%4s4p^{2}4f((^{3}P)^{4}P)^{5}G +5%4s4p^{2}4f((^{3}P)^{4}P)^{3}F
	-	361680.0	-	89%4s4p^{2}4f((^{3}P)^{4}P)^{5}F + 6%4s4p^{2}4f((^{3}P)^{4}P)^{5}G
	-	363758.0	-	89%4s4p^{2}4f((^{3}P)^{4}P)^{3}F + 5%4s4p^{2}4f((^{3}P)^{4}P)^{3}G

	-	383845.0	-	$72\%4s4p^24f((^1D)^2D)^1G + 19\%4p^34d(^2D)^1G$
	-	385513.0	-	$56\%4s4p^24f((^1D)^2D)^3F + 26\%4p^34d(^2D)^3F$
5	-	314207.0	-	$36\%4s^24p5g\ ^3H + 35\%4s^24p5g\ ^3G + 29\%4s^24p\ 5g\ ^1H$
	-	319446.0	-	$64\%4s^24p5g\ ^3G + 22\%4s^24p5g\ ^3H + 13\%4s^24p5g\ ^1H$
	-	320229.0	-	$58\%4s^24p5g\ ^1H + 41\%4s^24p5g\ ^3H$
	-	356797.0	-	$84\%4s4p^24f((^3P)^4P)^5G + 9\%4s4p^24f((^3P)^4P)^5F$ $+6\%4s4p^24f((^3P)^4P)^3G$
	-	359655.0	-	$83\%\ 4s4p^24f((^3P)^4P)^3G + 9\%4s4p^24f((^3P)^4P)^5G$
	-	361886.0	-	$88\%4s4p^24f((^3P)^4P)^5F + 6\%4s4p^24f((^3P)^4P)^5G$ $+5\%4s4p^24f((^3P)^4P)^3G$
6	-	320151.0	-	$100\%\ 4s^24p5g\ ^3H$
	-	358716.0	-	$98\%\ 4s4p^24f((^3P)^4P)^5G$

[a] The levels lie above the ionization potential are dropped from the table
[b] Difference between experimental energy levels and calculated energy levels.
[c] The LS components below 5% are dropped from the table.
[*] These levels were not fitted due to interaction, so not included in LSF calculation.

Table 4.4: LSF and HFR parameters of even parity configurations of Br IV in cm^{-1}

configuration	parameter	LSF	Accuracy	HF	LSF/HF
$4s^24p^2$	$E_{AV}(4s^24p^2)$	15074.4	328.0	16591.3	
	$F^2(4p,4p)$	48169.5	766.0	59672.0	0.807
	$\xi(4p)$	3653.9	250.0	3396.4	1.076
$4s^24p5p$	$E_{AV}(4s^24p5p)$	220782.6	139.0	227012.6	0.978
	$\xi(4p)$	3884.5	211.0	3739.5	1.039
	$\xi(5p)$	829.6	(fixed)	829.6	1.000
	$F^2(4p,5p)$	15758.2	743.0	18002.7	0.875
	$G^0(4p,5p)$	3379.6	135.0	4611.5	0.733
	$G^2(4p,5p)$	3554.6	597.0	5642.5	0.630
$4s^24p6p$	$E_{AV}(4s^24p6p)$	289842.6	(fixed)	295444.8	0.985
	$\xi(4p)$	3763.9	(fixed)	3764.0	1.000
	$\xi(6p)$	363.7	(fixed)	363.8	1.000
	$F^2(4p,6p)$	5736.2	(fixed)	7170.3	0.800
	$G^0(4p,6p)$	1158.5	(fixed)	1544.8	0.750
	$G^2(4p,6p)$	1548.5	(fixed)	2064.7	0.750
$4s^24p4f$	$E_{AV}(4s^24p4f)$	267591.2	193.0	273288.8	0.984
	$\xi(4p)$	4011.1	175.0	3738.6	1.073
	$\xi(4f)$	1.4	(fixed)	1.4	1.000
	$F^2(4p,4f)$	15441.6	(fixed)	18166.7	0.850
	$G^2(4p,4f)$	8085.6	940.0	10072.5	0.803
	$G^4(4p,4f)$	4997.4	(fixed)	6663.3	0.750
$4s^24p5f$	$E_{AV}(4s^24p5f)$	312828.2	144.0	315812.1	0.995
	$\xi(4p)$	3759.0	(fixed)	3759.1	1.000
	$\xi(5f)$	0.7	(fixed)	0.7	1.000
	$F^2(4p,5f)$	7308.4	1400.0	8227.6	0.888
	$G^2(4p,5f)$	4455.7	1063.0	5376.6	0.829
	$G^4(4p,5f)$	2713.9	(fixed)	3618.6	0.750
$4s4p^24d$	$E_{AV}(4s4p^24d)$	286028.2	105.0	289321.5	0.993
	$F^2(4p,4p)$	52940.1	1364.0	60679.7	0.872
	$\xi(4p)$	3551.5	(fixed)	3551.5	1.000
	$\xi(4d)$	173.5	(fixed)	173.6	0.999
	$F^2(4p,4d)$	36459.5	820.0	44654.9	0.816
	$G^1(4s,4p)$	61507.4	675.0	81422.3	0.755
	$G^2(4s,4d)$	26496.1	291.0	35075.2	0.755
	$G^1(4p,4d)$	39972.9	439.0	52915.4	0.755
	$G^3(4p,4d)$	24602.5	270.0	32568.5	0.755
$4s4p^25s$	$E_{AV}(4s4p^25s)$	303716.2	8529.0	306264.9	0.996
	$F^2(4p,4p)$	55809.4	72985.0	61561.3	0.910
	alfa(4p)	0.0	(fixed)		
	$\xi(4p)$	3679.4	(fixed)	3679.4	1.000
	$G^1(4s,4p)$	61866.0	(fixed)	82488.0	0.750
	$G^0(4s,5s)$	3447.7	(fixed)	4597.0	0.750
	$G^1(4p,5s)$	5040.0	(fixed)	6720.1	0.750
$4p^4$	$E_{AV}(4p^4)$	264562.1	1254.0	276153.0	0.961
	$F^2(4p,4p)$	57234.0	1858.0	59673.4	0.959
	$\xi(4p)$	3397.7	(fixed)	3397.7	1.000
R^k Parameters:					
$4s^24p^2$-$4s^24p5p$	$R^0(4p,4p;4p,5p)$	1464.9	44.0	2138.6	0.685
	$R^2(4p,4p;4p,5p)$	6788.9	203.0	9910.6	0.685
$4s^24p^2$-$4s^24p6p$	$R^0(4p,4p;4p,6p)$	812.4	(fixed)	1083.2	0.750

	$R^2(4p,4p;4p,6p)$	3489.7	(fixed)	4652.9	0.750
$4s^24p^2$ - $4s^24p4f$	$R^2(4p,4p;4p,4f)$	15653.4	467.0	22850.9	0.685
$4s^24p^2$ - $4s^24p5f$	$R^2(4p,4p;4p,5f)$	11817.3	353.0	17250.9	0.685
$4s^24p^2$ - $4s4p^24d$	$R^1(4s,4p;4p,4d)$	43489.5	1297.0	63486.1	0.685
	$R^2(4s,4p;4d,4p)$	31596.3	943.0	46124.4	0.685
$4s^24p^2$ - $4s4p^25s$	$R^0(4s,4s;4s,5s)$	3080.3	(fixed)	4107.0	0.750
	$R^1(4s,4p;4p,5s)$	1082.2	(fixed)	1443.0	0.750
	$R^0(4s,4p;5s,4p)$	265.8	(fixed)	354.4	0.750
$4s^24p^2$ - $4p^4$	$R^1(4s,4s;4p,4p)$	54954.6	1639.0	80222.9	0.685
$4s^24p5p$ - $4s^24p6p$	$R^2(4p,5p;4p,6p)$	5122.7	153.0	8012.3	0.639
	$R^0(4p,5p;6p,4p)$	1687.4	50.0	2639.3	0.639
	$R^2(4p,5p;6p,4p)$	2136.6	64.0	3341.8	0.639
$4s^24p5p$ - $4s^24p4f$	$R^2(4p,5p;4p,4f)$	-5406.3	-161.0	-8455.9	0.639
	$R^2(4p,5p;4f,4p)$	932.8	28.0	1459.0	0.639
$4s^2 4p5p$ - $4s^24p5f$	$R^2(4p,5p;4p,5f)$	-935.1	-28.0	-1462.7	0.639
	$R^2(4p,5p;5f,4p)$	1057.1	32.0	1653.4	0.639
$4s^24p5p$ - $4s4p^24d$	$R^1(4s,5p;4p,4d)$	-2328.9	-69.0	-3642.6	0.639
	$R^2(4s,5p;4d,4p)$	4251.8	127.0	6650.2	0.639
$4s^2 4p 5p$ - $4s4p^25s$	$R^1(4s,5p;4p,5s)$	20797.0	620.0	30359.6	0.685
	$R^0(4s,5p;5s,4p)$	2950.0	88.0	4306.4	0.685
$4s^24p6p$ - $4s^24p4f$	$R^2(4p,6p;4p,4f)$	-2041.3	(fixed)	-2916.2	0.700
	$R^2(4p,6p;4f,4p)$	191.9	(fixed)	274.1	0.700
$4s^24p 6p$ - $4s^24p5f$	$R^2(4p,6p;4p,5f)$	-2246.4	(fixed)	-3209.2	0.700
	$R^2(4p,6p;5f,4p)$	364.1	(fixed)	520.2	0.700
$4s^24p 6p$ - $4s4p^24d$	$R^1(4s,6p;4p,4d)$	-1360.4	(fixed)	-1943.4	0.700
	$R^2(4s,6p;4d,4p)$	2050.7	(fixed)	2929.6	0.700
$4s^24p6p$ - $4s4p^25s$	$R^1(4s,6p;4p,5s)$	9734.7	(fixed)	13906.7	0.700
	$R^0(4s,6p;5s,4p)$	1795.4	(fixed)	2564.8	0.700
$4s^24p4f$ - $4s^24p5f$	$R^2(4p,4f;4p,5f)$	6450.1	192.0	9415.9	0.685
	$R^2(4p,4f;5f,4p)$	4993.6	149.0	7289.7	0.685
	$R^4(4p,4f;5f,4p)$	3327.0	99.0	4856.8	0.685
$4s^24p4f$ - $4s4p^24d$	$R^1(4s,4f;4p,4d)$	23522.1	702.0	34337.6	0.685
	$R^2(4s,4f;4d,4p)$	12255.0	366.0	17889.9	0.685
$4s^24p5f$ - $4s4p^24d$	$R^1(4s,5f;4p,4d)$	15175.1	453.0	22152.6	0.685
	$R^2(4s,5f;4d,4p)$	9179.6	274.0	13400.4	0.685
$4s4p^24d$ - $4s4p^25s$	$R^2(4p,4d;4p,5s)$	-7378.3	(fixed)	-10540.5	0.700
	$R^1(4p,4d;5s,4p)$	-2114.8	(fixed)	-3021.3	0.700
$4s4p^24d$ - $4p^4$	$R^1(4s,4d;4p,4p)$	43104.0	1286.0	62923.5	0.685
$4s4p^25s$ - $4p^4$	$R^1(4s,5s;4p,4p)$	1142.1	34.0	1667.2	0.685
	Standard deviation σ	299.0			

The configuration interaction integrals for known configurations were linked to vary in the same ratio.

Table 4.5: LSF and HFR energy parameters in odd parity configurations of Br IV in cm^{-1}.

configuration	parameter	LSF	accuracy	HF	LSF/HF
$4s4p^3$	$E_{AV}(4s4p^3)$	138078.0	188.0	134471.1	1.043
	$F^2(4p,4p)$	52345.5	505.0	59660.1	0.877
	$\xi(4p)$	3394.7	(fixed)	3394.8	1.000
	$G^1(4s,4p)$	68727.2	271.0	80184.7	0.857
$4s^24p4d$	$E_{AV}(4s^24p4d)$	176229.7	876.0	178355.1	0.996
	$\xi(4p)$	3749.7	225.0	3561.1	1.053
	$\xi(4d)$	164.8	(fixed)	164.9	0.999
	$F^2(4p,4d)$	37158.6	899.0	43840.1	0.848
	$G^1(4p,4d)$	41865.7	526.0	51511.9	0.813
	$G^3(4p,4d)$	28897.8	970.0	31702.6	0.912
$4s^24p5d$	$E_{AV}(4s^24p5d)$	270145.1	87.0	276668.7	0.981
	$\xi(4p)$	4069.9	133.0	3733.8	1.090
	$\xi(5d)$	60.9	(fixed)	60.9	1.000
	$F^2(4p,5d)$	11438.8	838.0	12996.5	0.880
	$G^1(4p,5d)$	6203.7	422.0	9578.5	0.648
	$G^3(4p,5d)$	4925.6	(fixed)	6567.5	0.750
$4s^24p6d$	$E_{AV}(4s^24p6d)$	311365.0	105.0	318204.3	0.982
	$\xi(4p)$	4269.6	146.0	3761.6	1.135
	$\xi(6d)$	30.1	(fixed)	30.1	1.000
	$F^2(4p,6d)$	4900.2	1281.0	5753.6	0.852
	$G^1(4p,6d)$	2350.6	(fixed)	3791.4	0.620
	$G^3(4p,6d)$	1893.1	(fixed)	2704.4	0.700
$4s^24p7d$	$E_{AV}(4s^24p7d)$	340166.7	(fixed)	340173.7	1.005
	$\xi(4p)$	3771.7	(fixed)	3771.7	1.000
	$\xi(7d)$	17.3	(fixed)	17.3	1.000
	$F^2(4p,7d)$	2638.3	(fixed)	3103.9	0.850
	$G^1(4p,7d)$	1465.3	(fixed)	1953.7	0.750
	$G^3(4p,7d)$	1066.3	(fixed)	1421.9	0.750
$4s^24p5s$	$E_{AV}(4s^24p5s)$	188354.1	610.0	191655.2	0.990
	$\xi(4p)$	3685.1	(fixed)	3685.2	1.000
	$G^1(4p,5s)$	4092.5	791.0	6613.6	0.619
$4s^24p6s$	$E_{AV}(4s^24p6s)$	273677.6	160.0	280355.9	0.980
	$\xi(4p)$	4006.9	194.0	3750.1	1.068
	$G^1(4p,6s)$	1525.0	(fixed)	2033.5	0.750
$4s^24p7s$	$E_{AV}(4s^24p7s)$	313487.7	146.0	319817.5	0.984
	$\xi(4p)$	4087.5	182.0	3767.9	1.085
	$G^1(4p,7s)$	700.1	(fixed)	933.5	0.750
$4s^24p8s$	$E_{AV}(4s^24p8s)$	341041.7	(fixed)	341051.6	1.005
	$\xi(4p)$	3775.1	(fixed)	3775.1	1.000
	$G^1(4p,8s)$	384.8	(fixed)	513.2	0.750
$4s4p^25p$	$E_{AV}(4s4p^25p)$	340784.9	(fixed)	340788.3	1.005
	$F^2(4p,4p)$	52751.8	(fixed)	62061.0	0.850
	$\xi(4p)$	3730.9	(fixed)	3731.0	1.000
	$\xi(5p)$	832.1	(fixed)	832.2	1.000
	$F^2(4p,5p)$	15407.8	(fixed)	18126.8	0.850
	$G^1(4s,4p)$	62256.4	(fixed)	83008.5	0.750
	$G^1(4s,5p)$	5070.2	(fixed)	6760.3	0.750

	$G^0(4p,5p)$	3317.9	(fixed)	4423.9	0.750
	$G^2(4p,5p)$	4205.1	(fixed)	5606.8	0.750
$4s4p^24f$	$E_{AV}(4s4p^24f)$	387381.5	(fixed)	387382.7	1.004
	$F^2(4p,4p)$	52699.0	(fixed)	61998.8	0.850
	$\xi(4p)$	3730.1	(fixed)	3730.1	1.000
	$\xi(4f)$	1.4	(fixed)	1.5	0.933
	$F^2(4p,4f)$	15863.4	(fixed)	18662.9	0.850
	$G^1(4s,4p)$	62217.9	(fixed)	82957.3	0.750
	$G^3(4s,4f)$	4568.5	(fixed)	6091.4	0.750
	$G^2(4p,4f)$	7939.8	(fixed)	10586.4	0.750
	$G^4(4p,4f)$	5250.1	(fixed)	7000.2	0.750
$4p^34d$	$E_{AV}(4p^34d)$	424209.5	(fixed)	424210.6	1.004
	$F^2(4p,4p)$	51547.2	(fixed)	60643.8	0.850
	$\xi(4p)$	3545.9	(fixed)	3545.9	1.000
	$\xi(4d)$	183.2	(fixed)	183.3	0.999
	$F^2(4p,4d)$	38689.6	(fixed)	45517.3	0.850
	$G^1(4p,4d)$	40792.3	(fixed)	54389.8	0.750
	$G^3(4p,4d)$	25110.1	(fixed)	33480.2	0.750
$4p^35s$	$E_{AV}(4p^35s)$	445401.6	(fixed)	445411.8	1.004
	$F^2(4p,4p)$	52325.9	(fixed)	61559.9	0.850
	$\xi(4p)$	3677.7	(fixed)	3677.8	1.000
	$G^1(4p,5s)$	5159.4	(fixed)	6879.3	0.750
$4s^24p5g$	$E_{AV}(4s^24p5g)$	318195.9	(fixed)	318204.3	1.005
	$\xi(4p)$	3781.2	(fixed)	3781.3	1.000
	$\xi(5g)$	0.3	(fixed)	0.4	0.750
	$F^2(4p,5g)$	3688.7	(fixed)	4339.7	0.850
	$G^3(4p,5g)$	310.7	(fixed)	414.3	0.750
	$G^5(4p,5g)$	219.7	(fixed)	293.1	0.750
$4s4p4d^2$	$E_{AV}(4s4p4d^2)$	454609.0	(fixed)	454618.8	1.003
	$F^2(4d,4d)$	36957.0	(fixed)	43478.9	0.850
	$F^4(4d,4d)$	24534.7	(fixed)	28864.4	0.850
	$\xi(4p)$	3702.0	(fixed)	3702.1	1.000
	$\xi(4d)$	187.9	(fixed)	188.0	0.999
	$F^2(4p,4d)$	39004.3	(fixed)	45887.5	0.850
	$G^1(4s,4p)$	61926.6	(fixed)	82568.9	0.750
	$G^2(4s,4d)$	27383.0	(fixed)	36510.7	0.750
	$G^1(4p,4d)$	40924.4	(fixed)	54566.0	0.750
	$G^3(4p,4d)$	25229.0	(fixed)	33638.8	0.750
$4s4p5s^2$	$E_{AV}(4s4p5s2)$	502315.5	(fixed)	502321.6	1.003
	$\xi(4p)$	3970.8	(fixed)	3970.9	1.000
	$G^1(4s,4p)$	63502.4	(fixed)	84669.9	0.750
R^k Parameter:					
$4s4p^3$ -$4s^24p4d$	$R^1(4p,4p;4s,4d)$	53232.8	470.0	62063.9	0.858
$4s4p^3$ -$4s^24p5d$	$R^1(4p,4p;4s,5d)$	22878.4	202.0	26673.9	0.858
$4s4p^3$ -$4s^24p6d$	$R^1(4p,4p;4s,6d)$	14099.2	124.0	16438.2	0.858
$4s4p^3$ -$4s4p^24f$	$R^2(4p,4p;4p,4f)$	16426.6	(fixed)	23466.6	0.700
$4s4p^3$ -$4p^34d$	$R^1(4s,4p;4p,4d)$	63134.7	557.0	64407.4	0.980
$4s^24p4d$ -$4s^24p5d$	$R^0(4p,4d;4p,5d)$	1349.3	103.0	1970.8	0.685
	$R^2(4p,4d;4p,5d)$	9753.8	743.0	14246.1	0.685
	$R^1(4p,4d;5d,4p)$	14205.6	1082.0	20748.1	0.685
	$R^3(4p,4d;5d,4p)$	9119.3	695.0	13319.4	0.685
$4s^24p4d$ -$4s^24p7d$	$R^0(4p,4d;4p,7d)$	568.8	43.0	830.7	0.685
	$R^2(4p,4d;4p,7d)$	3666.3	279.0	5354.9	0.685
	$R^1(4p,4d;7d,4p)$	5950.5	453.0	8691.1	0.685
	$R^3(4p,4d;7d,4p)$	3835.1	292.0	5601.4	0.685
$4s^24p4d$ -$4s^24p5s$	$R^2(4p,4d;4p,5s)$	-7798.7	-594.0	-11390.5	0.685
	$R^1(4p,4d;5s,4p)$	-2573.1	-196.0	-3758.2	0.685

$4s^24p4d$ -$4s^24p6s$	$R^2(4p,4d;4p,6s)$	-3937.5	-300.0	-5751.0	0.685
	$R^1(4p,4d;6s,4p)$	-1802.1	-137.0	-2632.1	0.685
$4s^24p4d$ -$4s^24p7s$	$R^2(4p,4d;4p,7s)$	-2616.9	-199.0	-3822.1	0.685
	$R^1(4p,4d;7s,4p)$	-1321.1	-101.0	-1929.6	0.685
$4s^24p4d$ -$4s^24p8s$	$R^2(4p,4d;4p,8s)$	-1926.5	-147.0	-2813.7	0.685
	$R^1(4p,4d;8s,4p)$	-1019.4	-78.0	-1489.0	0.685
$4s^24p4d$ -$4s4p^25p$	$R^1(4s,4d;4p,5p)$	-3399.7	-259.0	-4965.4	0.685
	$R^1(4s,4d;5p,4p)$	7662.9	584.0	11192.1	0.685
$4s^24p4d$ -$4s4p^24f$	$R^1(4s,4d;4p,4f)$	24165.9	1841.0	35295.8	0.685
	$R^3(4s,4d;4f,4p)$	9617.0	733.0	14046.2	0.685
$4s^24p4d$ -$4p^34d$	$R^1(4s,4s;4p,4p)$	55727.5	4246.0	81393.6	0.685
$4s^24p4d$ -$4s^24p5g$	$R^2(4p,4d;4p,5g)$	-4364.6	-333.0	-6374.7	0.685
	$R^3(4p,4d;5g,4p)$	-2109.3	-161.0	-3080.8	0.685
$4s^24p4d$ -$4s4p4d^2$	$R^1(4s,4p;4p,4d)$	44514.6	3391.0	65016.5	0.685
	$R^2(4s,4p;4d,4p)$	32455.3	2473.0	47403.1	0.685
	$R^2(4s,4d;4d,4d)$	25214.9	1921.0	36828.1	0.685
$4s^24p5d$ -$4s^24p7d$	$R^2(4p,5d;4p,7d)$	3261.9	249.0	4764.1	0.685
	$R^1(4p,5d;7d,4p)$	2918.3	222.0	4262.3	0.685
	$R^3(4p,5d;7d,4p)$	2049.7	156.0	2993.8	0.685
$4s^24p5d$ -$4s^24p5s$	$R^2(4p,5d;4p,5s)$	4165.6	317.0	6084.1	0.685
	$R^1(4p,5d;5s,4p)$	692.3	53.0	1011.2	0.685
$4s^24p5d$ -$4s^24p6s$	$R^2(4p,5d;4p,6s)$	-1528.0	-116.0	-2231.7	0.685
	$R^1(4p,5d;6s,4p)$	55.6	4.0	81.3	0.684
$4s^24p5d$ -$4s^24p7s$	$R^2(4p,5d;4p,7s)$	-1040.3	-79.0	-1519.4	0.685
	$R^1(4p,5d;7s,4p)$	-52.8	-4.0	-77.1	0.685
$4s^24p5d$ -$4s^24p8s$	$R^2(4p,5d;4p,8s)$	-796.9	-61.0	-1164.0	0.685
	$R^1(4p,5d;8s,4p)$	-74.8	-6.0	-109.3	0.684
$4s^24p5d$ -$4s4p^25p$	$R^1(4s,5d;4p,5p)$	12086.2	921.0	17652.7	0.685
	$R^1(4s,5d;5p,4p)$	4430.8	338.0	6471.5	0.685
$4s^24p5d$ -$4s4p^24f$	$R^1(4s,5d;4p,4f)$	-828.6	-63.0	-1210.3	0.685
	$R^3(4s,5d;4f,4p)$	3912.9	298.0	5715.1	0.685
$4s^24p5d$ -$4s^24p5g$	$R^2(4p,5d;4p,5g)$	2001.0	152.0	2922.5	0.685
	$R^3(4p,5d;5g,4p)$	-652.8	-50.0	-953.4	0.685
$4s^24p5d$ -$4s4p4d^2$	$R^2(4s,5d;4d,4d)$	7959.1	606.0	11624.8	0.685
$4s^24p7d$ -$4s^24p5s$	$R^2(4p,7d;4p,5s)$	2918.3	222.0	4262.2	0.685
	$R^1(4p,7d;5s,4p)$	713.7	54.0	1042.4	0.685
$4s^24p7d$ -$4s^24p6s$	$R^2(4p,7d;4p,6s)$	1023.8	78.0	1495.3	0.685
	$R^1(4p,7d;6s,4p)$	245.6	19.0	358.7	0.685
$4s^24p7d$ -$4s^24p7s$	$R^2(4p,7d;4p,7s)$	237.0	18.0	346.2	0.685

	$R^1(4p,7d;7s,4p)$	121.4	9.0	177.2	0.685
$4s^24p7d$ -$4s^24p8s$	$R^2(4p,7d;4p,8s)$	-177.2	-13.0	-258.7	0.685
	$R^1(4p,7d;8s,4p)$	71.9	5.0	105.0	0.685
$4s^24p7d$ -$4s4p^25p$	$R^1(4s,7d;4p,5p)$	5538.7	422.0	8089.7	0.685
	$R^1(4s,7d;5p,4p)$	2200.0	168.0	3213.1	0.685
$4s^24p7d$ -$4s4p^24f$	$R^1(4s,7d;4p,4f)$	86.2	7.0	125.9	0.685
	$R^3(4s,7d;4f,4p)$	1616.8	123.0	2361.3	0.685
$4s^24p7d$ -$4s^24p5g$	$R^2(4p,7d;4p,5g)$	275.4	21.0	402.3	0.685
	$R^3(4p,7d;5g,4p)$	-221.1	-17.0	-322.9	0.685
$4s^24p7d$ -$4s4p4d^2$	$R^2(4s,7d;4d,4d)$	2916.8	222.0	4260.1	0.685
$4s^24p5s$ -$4s^24p6s$	$R^0(4p,5s;4p,6s)$	404.6	31.0	591.0	0.685
	$R^1(4p,5s;6s,4p)$	2412.5	184.0	3523.6	0.685
$4s^24p5s$ -$4s^24p7s$	$R^0(4p,5s;4p,7s)$	266.6	20.0	389.4	0.685
	$R^1(4p,5s;7s,4p)$	1584.9	121.0	2314.9	0.685
$4s^24p5s$ -$4s^24p8s$	$R^0(4p,5s;4p,8s)$	194.2	15.0	283.6	0.685
	$R^1(4p,5s;8s,4p)$	1153.0	88.0	1684.0	0.685
$4s^24p5s$ -$4s4p^25p$	$R^1(4s,5s;4p,5p)$	20814.4	1586.0	30400.7	0.685
	$R^1(4s,5s;5p,4p)$	3016.6	230.0	4406.0	0.685
$4s^24p5s$ -$4p^35s$	$R^1(4s,4s;4p,4p)$	56483.0	4303.0	82497.1	0.685
$4s^24p5s$ -$4s4p4d^2$	$R^2(4s,5s;4d,4d)$	-6906.0	-526.0	-10086.6	0.685
$4s^24p5s$ -$4s4p5s^2$	$R^0(4s,4s;4s,5s)$	2959.1	225.0	4321.9	0.685
	$R^1(4s,4p;4p,5s)$	1126.2	86.0	1644.8	0.685
	$R^0(4s,4p;5s,4p)$	263.9	20.0	385.5	0.685
	$R^0(4p,6s;4p,7s)$	398.2	30.0	581.6	0.685
$4s^24p6s$ -$4s^24p7s$	$R^1(4p,6s;7s,4p)$	0.0	(fixed)	0.0	
	$R^0(4p,6s;4p,8s)$	938.7	72.0	1371.2	0.685
$4s^24p6s$ -$4s^24p8s$	$R^1(4p,6s;8s,4p)$	0.0	(fixed)	0.0	
	$R^1(4s,6s;4p,5p)$	691.9	53.0	1010.5	0.685
$4s^24p6s$ -$4s4p^25p$	$R^1(4s,6s;5p,4p)$	4157.9	317.0	6072.9	0.685
	$R^2(4s,6s;4d,4d)$	1515.1	115.0	2212.8	0.685
$4s^24p6s$ -$4s4p5s^2$	$R^0(4s,4s;4s,5s)$	-3555.7	-271.0	-5193.3	0.685
$4s^24p6s$ -$4s4p5s^2$	$R^1(4s,4p;4p,5s)$	917.7	70.0	1340.4	0.685
$4s^24p6s$ -$4s4p5s^2$	$R^0(4s,4p;5s,4p)$	0.0	(fixed)	0.0	
	$R^0(4p,7s;4p,8s)$	473.3	36.0	691.3	0.685
$4s^24p7s$ -$4s^24p8s$	$R^1(4p,7s;8s,4p)$	2260.2	172.0	3301.1	0.685
	$R^1(4s,7s;4p,5p)$	962.0	73.0	1405.2	0.685
$4s^24p7s$ -$4s4p^25p$	$R^1(4s,7s;5p,4p)$	-2360.6	-180.0	-3447.7	0.685
$4s^24p7s$ -$4s4p4d^2$	$R^2(4s,7s;4d,4d)$	666.5	51.0	973.5	0.685
$4s^24p7s$ -$4s4p5s^2$	$R^0(4s,4s;4s,5s)$	1497.7	114.0	2187.6	0.685
	$R^1(4s,4p;4p,5s)$	685.3	52.0	1001.1	0.685

$4s^24p7s$ -$4s4p5s2$	$R^0(4s,4p;5s,4p)$	-1734.7	-132.0	-2533.6	0.685
$4s^24p8s$ -$4s4p^25p$	$R^1(4s,8s;4p,5p)$	507.2	39.0	740.8	0.685
$4s^24p8s$ -$4s4p^25p$	$R^1(4s,8s;5p,4p)$	-5927.0	-452.0	-8656.7	0.685
	$R^2(4s,8s;4d,4d)$	894.9	68.0	1307.0	0.685
$4s^24p8s$ -$4s4p5s^2$	$R^0(4s,4s;4s,5s)$	-2370.8	-181.0	-3462.7	0.685
	$R^1(4s,4p;4p,5s)$	4473.3	341.0	6533.5	0.685
	$R^2(4p,5p;4p,4f)$	3149.7	240.0	4600.3	0.685
$4s4p^25p$ -$4s4p^24f$	$R^2(4p,5p;4f,4p)$	-5171.0	-394.0	-7552.5	0.685
	$R^1(4s,5p;4p,4d)$	-1609.3	-123.0	-2350.5	0.685
$4s4p^25p$ -$4p^34d$	$R^2(4s,5p;4d,4p)$	-5818.1	-443.0	-8497.8	0.685
	$R^0(4s,5p;5s,4p)$	12678.4	966.0	18517.6	0.685
$4s4p^25p$ -$4s4p4d^2$	$R^1(4p,5p;4d,4d)$	-8904.0	-678.0	-13004.9	0.685
	$R^3(4p,5p;4d,4d)$	-964.2	-73.0	-1408.3	0.685
	$R^1(4s,4f;4p,4d)$	12821.9	977.0	18727.2	0.685
$4s4p^24f$ -$4p^34d$	$R^2(4s,4f;4d,4p)$	-6415.0	-489.0	-9369.7	0.685
	$R^1(4p,4f;4s,5g)$	-1295.7	-99.0	-1892.4	0.685
$4s4p^24f$ -$4s4p4d^2$	$R^1(4p,4f;4d,4d)$	1266.4	96.0	1849.7	0.685
$4s4p^24f$ -$4s4p4d^2$	$R^3(4p,4f;4d,4d)$	-3671.5	-280.0	-5362.4	0.685
	Standard deviation σ	264.0			

The configuration interaction integrals for known configurations were linked to vary in the same ratio; the remaining integrals fixed at 80% were not included in the table.

CHAPTER 5

The fifth spectrum of bromine: Br V

The Four-times ionized bromine (Br V) has neutral gallium- like (Ga I) spectrum with $4s^24p$ as the ground state configuration. The excited configurations are $4s4p^2$, $4s^2nd$ ($n \geq 4$) and $4s^2ns$ ($n \geq 5$). Further excitations lead to $4p^3+4s4p4d+4s4p5d+4s4p5s+4s4p6s+4s^2(5p+6p+7p+4f)+4s4p5p+4s4p4f+4s4p5f+4p^2(4d+5s)+4s^2(5g+6g+7g+..)$ etc. configurations. The spectrum of Br V was first analyzed by Rao and Rao[1]. They studied $4s^24p$, $4s4p^2$, $4s^2(4d+5d)$ configurations and classified 12 spectral lines in the wavelength region 482-856 Å. Budhiraja and Joshi [2] revised the earlier analysis of Rao and Rao [1] and reported 15 levels based on lines in the 468-1471Å region arising out of $4s^2(4p+5p)$ - $(4s4p^2+4s^24d+4s^25s)$ transition array and estimated the ionization potential of Br V at 502860 cm^{-1}. Recently, Tauheed and Joshi [3] investigated Br V spectrum in more detail. They studied the configurations $4s^2(4p+5p+6p+4f)+4s4p(4d+5s)+4p^3$ in the odd parity system and $4s^2(4d+5d+5s+6s+7s)+4s4p^2$ in the even parity matrix with theoretical predictions by Cowan's code [4] in the wavelength region 316 - 1892Å. They confirmed only 10 levels out of 15 reported by Budhiraja and Joshi [2], and revised 5 levels viz. $4s^25p$ $^2P_{1/2,\,3/2}$, $4s4p^2$ $^2S_{1/2}$, $^2D_{3/2}$ and $^2D_{5/2}$. Their analysis contained two hundred and sixteen classified lines connecting 57 energy levels and revised ionization limit at 480670±200 cm^{-1} (59.60±0.02 eV).

The present investigation is undertaken mainly due to the availability of the data in the shorter wavelength region (below 316Å)[5] as well as in the higher wavelength region above 2000Å[6] which led us to extend the study of new configurations like $4s^2(5g+6g+7p)$, $4s4p$ $(5p+4f)$ and $4p^24d$. Also, the availability of shorter wavelength data gave us a chance to verify the $4s^24p$-$4s^27s$ transitions which were missing in earlier work [3]. However, these transitions are not seen on the list and a revised level value of $4s^27s$ $^2S_{1/2}$ is found at 381546.60 cm^{-1} giving satisfactory transitions. This revision changes the value of the ionization energy [3].

5.1 The energy level structure:

The electronic distribution for ground state configuration of four times ionized bromine (Br V) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p$ gives rise to two energy levels namely $^2P_{1/2}$ and $^2P_{3/2}$.

The excited configurations of interest with associated energy levels are listed as below:

$4s4p^2$:		$(^3P)^4P_{1/2,3/2,5/2}$
		$(^3P)^2P_{1/2,3/2}$
		$(^1S)^2S_{1/2}$
		$(^1D)\ ^2D_{3/2,5/2}$
$4s^2nd$ ($n\geq4$):		$^2D_{3/2,5/2}$
$4s^2ns$ ($n\geq5$):		$^2S_{1/2}$
$4s^2ng$ ($n\geq5$):		$^2G_{7/2,9/2}$
$4s^2np$ ($n\geq5$):		$^2P_{1/2,3/2}$
$4s4p4d$:	(^3P)	$^4F_{3/2,5/2,7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^4D_{1/2,3/2,5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1P)	$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
$4s4p5p$:	(^3P)	$^4D_{1/2,3/2,5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
		$^4S_{3/2}$
		$^2S_{1/2}$
	(^1P)	$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
		$^2S_{1/2}$
$4s4p4f$:	(^3P)	$^4G_{5/2,7/2,9/2}$
		$^2G_{7/2,9/2}$
		$^4F_{3/2,5/2,7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^4D_{1/2,3/2,5/2,7/2}$
		$^2D_{3/2,5/2}$
	(^1P)	$^2G_{7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$

$4p^2 4d$:	(^3P)	$^4F_{3/2,5/2,7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^4D_{1/2,3/2,5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1D)	$^2G_{7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
		$^2S_{1/2}$
	(^1S)	$^2D_{3/2,5/2}$
$4p^2 5s$:	(^3P)	$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1D)	$^2D_{5/2}$
	(^1S)	$^2S_{1/2}$
$4s^2 4f$:		$^2F_{5/2,7/2}$
$4p^3$:		$^4S_{3/2}$
		$^2P_{1/2,3/2}$
		$^2D_{3/2,5/2}$
$4s4p5s$:	(^3P)	$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1P)	$^2P_{1/2,3/2}$
$4p4d^2$:	(^3F)	$^4G_{5/2,7/2,9/2,11/2}$
		$^2G_{7/2,9/2}$
		$^4F_{3/2,5/2,7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^4D_{1/2,3/2,5/2,7/2}$
		$^2D_{3/2,5/2}$
	(^3P)	$^4D_{1/2,3/2,5/2,7/2}$
		$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
		$^2D_{3/2,5/2}$
		$^4S_{3/2}$
		$^2S_{1/2}$
	(^1G)	$^2H_{9/2,11/2}$
		$^2G_{7/2,9/2}$
		$^2F_{5/2,7/2}$
	(^1D)	$^2F_{5/2,7/2}$

		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1S)	$^2P_{1/2,3/2}$
$4p5s^2$:		$^2P_{1/2,3/2}$
$4p^25p$:	(^3P)	$^4D_{1/2,3/2,5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^4P_{1/2,3/2,5/2}$
		$^2P_{1/2,3/2}$
		$^4S_{3/2}$
		$^2S_{1/2}$
	(^1D)	$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1S)	$^2P_{1/2,3/2}$
$4p^24f$:	(^3P)	$^4G_{5/2,7/2,9/2,11/2}$
		$^2G_{7/2,9/2}$
		$^4F_{3/2,5/2,7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^4D_{1/2,3/2,5/2,7/2}$
		$^2D_{3/2,5/2}$
	(^1D)	$^2H_{9/2,11/2}$
		$^2G_{7/2,9/2}$
		$^2F_{5/2,7/2}$
		$^2D_{3/2,5/2}$
		$^2P_{1/2,3/2}$
	(^1S)	$^2F_{5/2,7/2}$

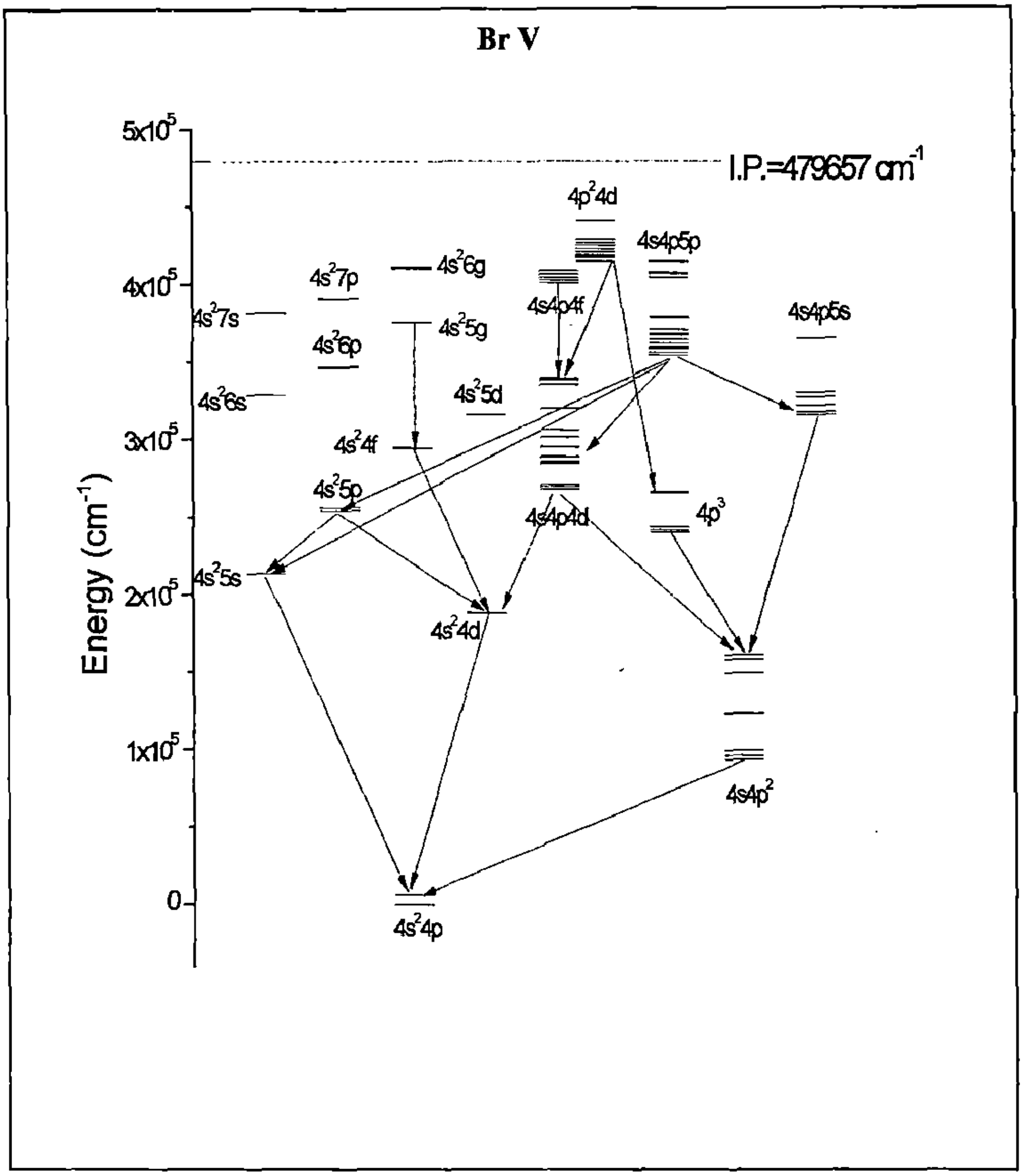

Fig. 5.1: Energy level diagram of Br V. The configurations shown in black colour are analyzed in earlier work [3] and that shown in red colour are studied in the present work.

5.2 Theoretical calculations:

The ab initio prediction for this spectrum was obtained by using Cowan's code [4] in HFR mode by superposition of configurations. The prominent interacting configurations incorporated for odd parity system were $4s^2(5p+6p+7p+8p+4f)$ + $4s4p(4d+5d+ 5s+6s)$ + $4p^3+4p4d^2+$ $4p5s^2$ $+4p^25p+$ $4p^24f$ and that for even parity matrix were $4s4p^2$ + $4s^2$ $(4d + 5d + 6d + 5s + 6s + 7s + 8s + 9s+5g+6g+7g+8g)$ +

$4p^24d + 4p^25s + 4s4p5p + 4s4p4f$ for a reliable prediction. The *ab initio* values for different energy parameters used were as E_{av} and ζ at 100%, F^k at 85%, G^k and R^k at 75% of HFR values. Further, this scaling was refined by comparing the parameters with its isoelectronic ion Kr^{5+} [7,8]. As the analysis progressed, the least squares fitted parametric ,calculations were performed and finally energy parameters were obtained from least squares fit and they are given in Tables 5.4 & 5.5. Due to convergence problem in LSF calculations, some of the low configuration interaction integrals (R^k) have been fixed at predetermined values.

5.3 Analysis and discussion

5.31 New Analysis:

With the availability of extended data in shorter as well as in longer wavelength regions, it became possible to look for new configurations $4s^2(5g+6g+7p)$, 4s4p5p, 4s4p4f and $4p^2(4d+5s)$ which were not studied before. The analysis started with the verification of published work [3]. It was found that all the levels were correct except $4s^27s\ ^2S_{1/2}$. This level did not give any transition from $4s^24p$ levels and hence created doubt. Though, on isoelectronic extrapolation it was not too far from the expected value. However, on new line list, these transitions were located giving level value at 381546.60 cm^{-1} which is only 348.4 cm^{-1} lower than earlier value. This was further confirmed by the observed transitions from $4s^25p$ levels. Level optimization done using computer code LOPT [9], allowed minor adjustment in level values of Ref 3.

5.32 The $4s^2ng$ configurations:

The $4s^2ng$ series were considered next. We expected strong transitions from $4s^24f$ levels. However, it was noticed that $4s^26g$ and $4s^27g$ levels were highly mixed with 4s4p4f and $4p^24d$ configurations which resulted in unusually large ^2G interval. Secondly, $4s^24f\ ^2F$ levels were also mixed with 4s4p4d levels. Due to these mixings the 4f - ng transitions were not that regular as expected. The 6g interval was highly perturbed and was found to be much larger than 5g interval. Strong transitions from 4s4p4d were also predicted. The situation of $4s^25g$ was better and we could found 4f - 5g transitions easily. The 6g levels were found satisfactorily with large separation of 749 cm^{-1} as predicted on the basis of transitions from $4s^24f$ and 4s4p4d levels. The 7g levels, predicted with separation 93 cm^{-1} were not so clear; we could not found any satisfactory pair for them and were left out.

5.33 The 4s4p5p configuration: This configuration arises from the excitation of 4s4p4d, 4s4p5s and $4s^25p$ configurations. The array [$4s4p4d+4s4p5s+4s^25p$ – 4s4p5p] is found to be reasonably strong on our plates. Since the configurations $4p^3$, 4s4p4d and 4s4p5s are strongly mixed with each other, fairly strong transitions from $4p^3$ are also observed and we are successful to establish all the 18 levels of this configuration. The LS purity of all the levels are greater than 50% except that of (^3P) $^2P_{3/2}$ at 359047.4, (^3P)$^4S_{3/2}$ at 367255.2 and (^3P)$^2D_{3/2}$ at 368235.0 cm^{-1} which are 46%, 47% and 43% respectively. Thus LS designation is still quite unambiguous. These levels are nicely fitting in the least squares parametric calculations with expected parameters scaling.

5.34 The 4s4p4f configuration: The theoretical prediction for this configuration was obtained with the inclusion of all interacting configurations as mentioned-above. The transitions lying on our plates and predicted strong were looked first. It was easy to locate the first level 4s4p4f (^3P) $^2G_{7/2}$ at 406484.2 cm^{-1} based on the identifications of 5 transitions. This established the initial shift from the calculated value. A further scaling of the E_{av} (4s4p4f) gave very precise prediction of the remaining 4s4p4f levels. A few transitions from $4p^3$ were also observed due to strong mixing of $4p^3$ with 4s4p4d as mentioned above. We established 6 levels of this configuration satisfactorily. A few more levels were also found with less satisfaction, so we did not include them here. The LS designations were not unambiguous as their leading LS purities were greater than 50% except (^3P) $^4D_{7/2}$ at 402576.4 cm^{-1} which is 44%.

5.35 The $4p^24d$ configuration:

The $4p^24d$ configuration is strongly mixed with 4s4p4f. On the other side, $4s^24f$ and $4p^3$ configurations are mixed with 4s4p4d as mentioned earlier. Therefore, transitions from $4s^24f$ were also observed along with 4s4p4d and $4p^3$ configurations. We were able to establish 12 levels out of 28 of the $4p^24d$ configuration. LS designations are still unambiguous for observed levels. The least squares fitted parameters were found to be in close agreement with Kr VI [7] which is isoelectronic to Br V.

5.4 Results:

The levels were optimized using LOPT [9] code of Dr. A. E. Kramida of NIST [USA]. The transition probabilities (gA) and weighted oscillator strength (log gf) as obtained with final least squares fitted energy parameters are included in Table 5.1. The optimized levels along with their uncertainties and the number of connecting lines as obtained by LOPT program are given in Table 5.2. The observed and the least squares fitted (LSF) energy levels along with their LS percentage mixing are assembled in Table 5.3 and the corresponding energy parameters of both odd and even parity configurations are given in Table 5.4 & 5.5 respectively. 99 levels of Br V have now been established, 43 being new. Among 394 classified spectral lines, 181 are new. We found reasonably good agreement of observed levels with the theoretical calculations. The standard deviations for odd and even parity configurations were 166 and 360 cm^{-1} respectively.

5.41 Ionization potential

Tauheed and Joshi [3] reported the ionization limit of Br V at 480670 ± 200 cm^{-1} based on three member series $4s^2ns$ (n = 5–7). Since $4s^27s$ level has been revised, so the new value of the ionization potential is found to be 479657 cm^{-1} using the non linear least-squares fitting computer code RITZPL [10,11]. A similar calculation of I.P. for As III [12] which is isoelectronic to Br V was carried out using $4s^2ns$ as well as $4s^2ng$ series. We found that the limit calculated by $4s^2ng$ series was about 100 cm^{-1} higher than $4s^2ns$ series. Therefore we considered the similar amount of uncertainty in Br V as well and adapted the series limit of Br V at 479657 ±200 cm^{-1} (59.470 ± 0.025 eV).

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Table 5.1: Classified lines of Br V.

I_{obs}[a]	λ_{obs}(Å)	σ_{obs}(cm^{-1})	λ_{Ritz}(Å)	$\lambda_{obs}-\lambda_{Ritz}$(Å)[b]	Lower level	Upper level	Log gf	gA(s^{-1})[c]
10	248.979	401640	248.983	-0.004	$4s^24p\ ^2P_{3/2}$	$4s4p5p\ (^1P)\ ^2D_{5/2}$	-1.455	3.775E+09
32	262.095	381541	262.091	0.004	$4s^24p\ ^2P_{1/2}$	$4s^27s\ ^2S_{1/2}$	-1.682	2.020E+09
42	266.346	375451	266.340	0.006	$4s^24p\ ^2P_{3/2}$	$4s^27s\ ^2S_{1/2}$	-1.357	4.133E+09
15	268.174	372892	268.175	-0.001	$4s^24p\ ^2P_{3/2}$	$4s4p5p\ (^3P)\ ^2S_{1/2}$	-2.776	1.554E+08
20	271.564	368237	271.566	-0.002	$4s^24p\ ^2P_{1/2}$	$4s4p5p\ (^3P)\ ^2D_{3/2}$	-1.997	9.130E+08
11	272.289	367257	272.290	-0.001	$4s^24p\ ^2P_{1/2}$	$4s4p5p\ (^3P)\ ^4S_{3/2}$	-1.895	1.147E+09
28	274.021	364936	274.019	0.002	$4s^24p\ ^2P_{3/2}$	$4s4p5p\ (^3P)\ ^2D_{5/2}$	-1.276	4.725E+09
16	276.130	362148	276.129	0.001	$4s^24p\ ^2P_{1/2}$	$4s4p5p\ (^3P)\ ^4P_{3/2}$	-2.376	3.679E+08
16	276.130	362148	276.130	0	$4s^24p\ ^2P_{3/2}$	$4s4p5p\ (^3P)\ ^2D_{3/2}$	-1.910	1.079E+09
28	277.692	360111	277.693	-0.001	$4s^24p\ ^2P_{1/2}$	$4s4p5p\ (^3P)\ ^4P_{1/2}$	-2.509	2.676E+08
18	280.726	356219	280.728	-0.002	$4s^24p\ ^2P_{1/2}$	$4s4p5p\ (^3P)\ ^4D_{3/2}$	-2.632	1.979E+08
20	280.854	356057	280.849	0.005	$4s^24p\ ^2P_{3/2}$	$4s4p5p\ (^3P)\ ^4P_{3/2}$	-2.262	4.624E+08
20	282.132	354444	282.131	0.001	$4s^24p\ ^2P_{1/2}$	$4s4p5p\ (^3P)\ ^4D_{1/2}$	-2.413	3.240E+08
22	285.604	350135	285.609	-0.005	$4s^24p\ ^2P_{3/2}$	$4s4p5p\ (^3P)\ ^4D_{3/2}$	-2.317	3.948E+08
8	287.059	348360	287.061	-0.002	$4s^24p\ ^2P_{3/2}$	$4s4p5p\ (^3P)\ ^4D_{1/2}$	-2.912	9.908E+07
40	316.521[d]	315935	316.521	0	$4s^24p\ ^2P_{1/2}$	$4s^25d\ ^2D_{3/2}$	-1.124	4.999E+09
50	322.490[d]	310087	322.485	0.005	$4s^24p\ ^2P_{3/2}$	$4s^25d\ ^2D_{5/2}$	-0.875	8.547E+09
25	322.737[d]	309850	322.739	-0.002	$4s^24p\ ^2P_{3/2}$	$4s^25d\ ^2D_{3/2}$	-1.815	9.801E+08
20	373.294	267885	373.297	-0.003	$4s4p^2\ ^2D_{3/2}$	$4s^27p\ ^2P_{1/2}$	-1.922	5.736E+08
25	373.340	267852	373.344	-0.004	$4s4p^2\ ^2D_{5/2}$	$4s^27p\ ^2P_{3/2}$	-1.633	1.116E+09
10	412.317[d]	242532	412.315	0.002	$4s4p^2\ ^2D_{3/2}$	$4s4p5s\ (^1P)\ ^2P_{3/2}$	-1.315	1.900E+09
60	412.535[d]	242404	412.535	0	$4s4p^2\ ^2D_{3/2}$	$4s4p5s\ (^1P)\ ^2P_{1/2}$	-0.755	6.904E+09
70	413.558[d]	241804	413.559	-0.001	$4s4p^2\ ^2D_{5/2}$	$4s4p5s\ (^1P)\ ^2P_{3/2}$	-0.624	9.296E+09
5	424.020[d]	235838	424.015	0.005	$4s4p^2\ ^4P_{5/2}$	$4s4p4d\ (^1P)\ ^2F_{7/2}$	-1.943	4.225E+08
5	427.060[d]	234159	427.063	-0.003	$4s4p^2\ ^4P_{3/2}$	$4s4p5s\ (^3P)\ ^2P_{3/2}$	-2.294	1.857E+08
5	429.904	232610	429.903	0.001	$4s4p^2\ ^2P_{1/2}$	$4s^27p\ ^2P_{1/2}$	-2.932	4.220E+07
40	442.155[d]	226165	442.157	-0.002	$4s4p^2\ ^4P_{1/2}$	$4s4p4d\ (^3P)\ ^2P_{3/2}$	-1.128	2.539E+09
90	442.577[d]	225949	442.573	0.004	$4s4p^2\ ^4P_{3/2}$	$4s4p5s\ (^3P)\ ^4P_{5/2}$	-0.352	1.512E+10
100	446.301[d]	224064	446.304	-0.003	$4s4p^2\ ^4P_{1/2}$	$4s4p5s\ (^3P)\ ^4P_{3/2}$	-0.476	1.120E+10
20	447.040[d]	223694	447.042	-0.002	$4s4p^2\ ^4P_{3/2}$	$4s4p4d\ (^3P)\ ^2P_{3/2}$	-1.624	7.925E+08
10	447.569[d]	223429	447.565	0.004	$4s4p^2\ ^2D_{3/2}$	$4s^26p\ ^2P_{1/2}$	-1.831	4.922E+08
100	449.137[d]	222649	449.139	-0.002	$4s4p^2\ ^4P_{5/2}$	$4s4p5s\ (^3P)\ ^4P_{5/2}$	-0.006	3.252E+10

15	450.046[d]	222200	450.040	0.006	$4s4p^2$	$^4P_{1/2}$	$4s4p5s\,(^3P)\,^4P_{1/2}$	-1.108	2.573E+09
80	451.281[d]	221591	451.282	-0.001	$4s4p^2$	$^4P_{3/2}$	$4s4p5s\,(^3P)\,^4P_{3/2}$	-1.024	3.098E+09
40	453.739[d]	220391	453.742	-0.003	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\,(^3P)\,^2P_{3/2}$	-1.505	1.012E+09
65	455.101[d]	219731	455.102	-0.001	$4s4p^2$	$^4P_{3/2}$	$4s4p5s\,(^3P)\,^4P_{1/2}$	-0.434	1.186E+10
90	458.106[d]	218290	458.111	-0.005	$4s4p^2$	$^4P_{5/2}$	$4s4p5s\,(^3P)\,^4P_{3/2}$	-0.405	1.249E+10
40	463.108[d]	215932	463.104	0.004	$4s4p^2$	$^2S_{1/2}$	$4s4p5s\,(^1P)\,^2P_{3/2}$	-0.670	6.638E+09
95	468.375[d]	213504	468.377	-0.002	$4s^24p$	$^2P_{1/2}$	$4s^25s$ $^2S_{1/2}$	-0.552	8.535E+09
60	469.644[d]	212927	469.644	0	$4s4p^2$	$^2D_{3/2}$	$4s4p4d\,(^1P)\,^2F_{5/2}$	0.170	4.481E+10
40	471.260[d]	212197	471.258	0.002	$4s4p^2$	$^2D_{5/2}$	$4s4p4d\,(^1P)\,^2F_{5/2}$	-1.066	2.587E+09
75	472.770[d]	211519	472.763	0.007	$4s4p^2$	$^2D_{5/2}$	$4s4p4d\,(^1P)\,^2F_{7/2}$	0.277	5.653E+10
100	482.121[d]	207417	482.122	-0.001	$4s^24p$	$^2P_{3/2}$	$4s^25s$ $^2S_{1/2}$	-0.264	1.561E+10
60	482.472[d]	207266	482.473	-0.001	$4s4p^2$	$^2D_{3/2}$	$4s4p5s\,(^3P)\,^2P_{3/2}$	-1.083	2.373E+09
60	482.789[d]	207130	482.786	0.003	$4s4p^2$	$^2P_{1/2}$	$4s4p5s\,(^1P)\,^2P_{1/2}$	-0.598	7.223E+09
45	483.530[d]	206812	483.538	-0.008	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\,(^3P)\,^2F_{7/2}$	-1.305	1.413E+09
90	484.178[d]	206536	484.177	0.001	$4s4p^2$	$^2D_{5/2}$	$4s4p5s\,(^3P)\,^2P_{3/2}$	0.030	3.056E+10
50	486.692[d]	205469	486.692	0	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\,(^3P)\,^2F_{5/2}$	-2.067	2.414E+08
80	489.115[d]	204451	489.125	-0.01	$4s4p^2$	$^2D_{3/2}$	$4s4p5s\,(^3P)\,^2P_{1/2}$	-0.417	1.067E+10
85	489.221[d]	204407	489.219	0.002	$4s4p^2$	$^2P_{3/2}$	$4s4p5s\,(^1P)\,^2P_{3/2}$	-0.321	1.332E+10
30	489.532[d]	204277	489.528	0.004	$4s4p^2$	$^2P_{3/2}$	$4s4p5s\,(^1P)\,^2P_{1/2}$	-1.021	2.649E+09
20	492.930	202869	492.937	-0.007	$4s^24d$	$^2D_{5/2}$	$4s^27p$ $^2P_{3/2}$	-1.533	8.027E+08
40	496.743[d]	201311	496.747	-0.004	$4s4p^2$	$^4P_{1/2}$	$4s4p4d\,(^3P)\,^2D_{3/2}$	-1.507	8.424E+08
60	500.961	199616	500.963	-0.002	$4p^3$	$^2D_{5/2}$	$4p^24d\,(^1D)\,^2D_{5/2}$	0.251	4.684E+10
60	501.702[d]	199322	501.704	-0.002	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\,(^3P)\,^2D_{5/2}$	-1.214	1.620E+09
5	502.918[d]	198840	502.921	-0.003	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\,(^3P)\,^2D_{3/2}$	-2.130	1.958E+08
20	504.203[d]	198333	504.199	0.004	$4s4p^2$	$^4P_{3/2}$	$4s^24f$ $^2F_{5/2}$	-2.163	1.804E+08
5	505.394[d]	197865	505.387	0.007	$4s4p^2$	$^2S_{1/2}$	$4s^26p$ $^2P_{3/2}$	-3.258	1.440E+07
50	506.653[d]	197374	506.652	0.001	$4s4p^2$	$^2D_{3/2}$	$4s4p4d\,(^3P)\,^2P_{1/2}$	-0.632	6.071E+09
10	508.052[d]	196830	508.047	0.005	$4s4p^2$	$^2S_{1/2}$	$4s^26p$ $^2P_{1/2}$	-1.525	7.694E+08
70	510.021[d]	196070	510.019	0.002	$4s4p^2$	$^2D_{5/2}$	$4s4p4d\,(^3P)\,^2P_{3/2}$	-1.019	2.459E+09
60	511.936[d]	195337	511.931	0.005	$4s4p^2$	$^4P_{5/2}$	$4s^24f$ $^2F_{7/2}$	-1.324	1.205E+09
10	512.740[d]	195031	512.738	0.002	$4s4p^2$	$^4P_{5/2}$	$4s^24f$ $^2F_{5/2}$	-2.082	2.098E+08
10	513.610[d]	194700	513.613	-0.003	$4s4p^2$	$^2D_{3/2}$	$4s4p5s\,(^3P)\,^4P_{3/2}$	-1.891	3.253E+08
20	515.544[d]	193970	515.544	0	$4s4p^2$	$^2D_{5/2}$	$4s4p5s\,(^3P)\,^4P_{3/2}$	-1.408	9.833E+08
60	517.544[d]	193220	517.545	-0.001	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\,(^3P)\,^4P_{3/2}$	0.317	5.158E+10
90	517.653[d]	193180	517.649	0.004	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\,(^3P)\,^4D_{5/2}$	0.163	3.620E+10

65	518.017[d]	193044	518.027	-0.01	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\ (^3P)\ ^4P_{1/2}$	0.168	3.656E+10
5	518.560[d]	192842	518.567	-0.007	$4s4p^2$	$^2D_{3/2}$	$4s4p5s\ (^3P)\ ^4P_{1/2}$	-2.036	2.286E+08
65	520.270[d]	192208	520.273	-0.003	$4s4p^2$	$^4P_{1/2}$	$4s4p4d\ (^3P)\ ^4D_{1/2}$	0.289	4.805E+10
100	521.771[d]	191655	521.767	0.004	$4s4p^2$	$^4P_{1/2}$	$4s4p4d\ (^3P)\ ^4D_{3/2}$	0.446	6.880E+10
60	525.634[d]	190246	525.628	0.006	$4s4p^2$	$^2S_{1/2}$	$4s4p4d\ (^1P)\ ^2P_{3/2}$	-0.376	1.015E+10
55	526.545[d]	189917	526.546	-0.001	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\ (^3P)\ ^4P_{3/2}$	0.095	2.987E+10
100	526.651[d]	189879	526.654	-0.003	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\ (^3P)\ ^4D_{5/2}$	0.611	9.811E+10
20	527.051[d]	189735	527.050	0.001	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\ (^3P)\ ^4D_{1/2}$	-1.848	3.409E+08
100	527.860[d]	189444	527.858	0.002	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\ (^3P)\ ^4D_{7/2}$	0.901	1.905E+11
40	528.564	189192	528.558	0.006	$4s4p^2$	$^2P_{1/2}$	$4s^26p\ \ ^2P_{3/2}$	-1.270	1.283E+09
60	528.587[d]	189184	528.583	0.004	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\ (^3P)\ ^4D_{3/2}$	-0.314	1.159E+10
70	528.725[d]	189134	528.728	-0.003	$4s4p^2$	$^2S_{1/2}$	$4s4p4d\ (^1P)\ ^2P_{1/2}$	-0.190	1.543E+10
10	529.795[d]	188752	529.785	0.010	$4s4p^2$	$^2S_{1/2}$	$4s4p4d\ (^1P)\ ^2D_{3/2}$	-1.480	7.880E+08
100	530.798[d]	188396	530.791	0.007	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\ (^3P)\ ^4P_{5/2}$	0.592	9.250E+10
10	531.474[d]	188156	531.468	0.006	$4s4p^2$	$^2P_{1/2}$	$4s^26p\ \ ^2P_{1/2}$	-1.130	1.748E+09
125	531.962[d]	187983	531.961	0.001	$4s^24p$	$^2P_{1/2}$	$4s^24d\ ^2D_{3/2}$	0.453	6.689E+10
30	536.649[d]	186342	536.649	0	$4s4p^2$	$^2P_{3/2}$	$4s^26p\ ^2P_{3/2}$	-0.594	5.907E+09
40	537.979[d]	185881	537.976	0.003	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\ (^3P)\ ^4D_{3/2}$	-0.824	3.451E+09
50	538.922	185556	538.922	0	$4p^3$	$^4S_{3/2}$	$4p^24d\ \ (^3P)\ ^4P_{5/2}$	0.768	1.347E+11
10	539.649[d]	185306	539.649	0	$4s4p^2$	$^2P_{3/2}$	$4s^26p\ ^2P_{1/2}$	-1.223	1.370E+09
80	540.271[d]	185092	540.263	0.008	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\ (^3P)\ ^4P_{5/2}$	-0.274	1.214E+10
5	546.736	182904	546.729	0.007	$4p^3$	$^2D_{3/2}$	$4p^24d\ \ (^3P)\ ^4D_{5/2}$	-0.741	4.070E+09
150	547.879[d]	182522	547.877	0.002	$4s^24p$	$^2P_{3/2}$	$4s^24d\ \ ^2D_{5/2}$	0.707	1.132E+11
95	547.980[d]	182488	547.973	0.007	$4s4p^2$	$^2D_{5/2}$	$4s4p4d\ (^3P)\ ^2F_{7/2}$	0.655	1.007E+11
100	549.760[d]	181898	549.762	-0.002	$4s^24p$	$^2P_{3/2}$	$4s^24d\ \ ^2D_{3/2}$	-0.180	1.458E+10
80	553.502[d]	180668	553.505	-0.003	$4s4p^2$	$^2S_{1/2}$	$4s4p5s\ (^3P)\ ^2P_{3/2}$	0.029	2.325E+10
80	554.138[d]	180460	554.142	-0.004	$4s4p^2$	$^2P_{1/2}$	$4s4p4d\ (^1P)\ ^2P_{1/2}$	-0.288	1.121E+10
100	555.306[d]	180081	555.304	0.002	$4s4p^2$	$^2P_{1/2}$	$4s4p4d\ (^1P)\ ^2D_{3/2}$	0.665	9.981E+10
10	557.011	179530	557.015	-0.004	$4p^3$	$^4S_{3/2}$	$4p^24d\ \ (^3P)\ ^4D_{5/2}$	-0.391	8.769E+09
10	557.121	179494	557.112	0.009	$4p^3$	$^2D_{5/2}$	$4p^24d\ \ (^1D)\ ^2F_{7/2}$	0.020	2.246E+10
10	558.683	178992	558.679	0.004	$4p^3$	$^2D_{3/2}$	$4p^24d\ \ (^1D)\ ^2F_{5/2}$	-0.156	1.499E+10
95	559.529[d]	178722	559.528	0.001	$4s4p^2$	$^2P_{3/2}$	$4s4p4d\ (^1P)\ ^2P_{3/2}$	0.509	6.885E+10
100	559.760[d]	178648	559.766	-0.006	$4s4p^2$	$^2P_{3/2}$	$4s4p4d\ (^1P)\ ^2D_{5/2}$	0.903	1.698E+11
90	559.989[d]	178575	559.982	0.007	$4s4p^2$	$^2D_{3/2}$	$4s4p4d\ (^3P)\ ^2F_{5/2}$	0.460	6.151E+10

85	562.278[d]	177848	562.279	-0.001	$4s4p^2$	$^2D_{5/2}$	$4s4p4d\,(^3P)\,^2F_{5/2}$	-0.165	1.449E+10
85	562.278[d]	177848	562.279	-0.001	$4s4p^2$	$^2S_{1/2}$	$4s4p5s\,(^3P)\,^2P_{1/2}$	-0.078	1.758E+10
60	563.038[d]	177608	563.042	-0.004	$4s4p^2$	$^2P_{3/2}$	$4s4p4d\,(^1P)\,^2P_{1/2}$	-0.267	1.142E+10
95	563.947[B]	177322	563.963	-0.016	$4s^24d$	$^2D_{3/2}$	$4s4p5s\,(^1P)\,^2P_{1/2}$	-0.871	2.820E+09
30	564.246[d]	177228	564.241	0.005	$4s4p^2$	$^2P_{3/2}$	$4s4p4d\,(^1P)\,^2D_{3/2}$	-1.524	6.261E+08
10	565.545[d]	176821	565.548	-0.003	$4s^24d$	$^2D_{5/2}$	$4s4p5s\,(^1P)\,^2P_{3/2}$	-0.724	3.938E+09
30	567.982[B]	176062	567.992	-0.01	$4p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)\,^4F_{3/2}$	-0.833	2.969E+09
20	572.074[d]	174803	572.076	-0.002	$4s4p^2$	$^2P_{3/2}$	$4s4p4d\,(^1P)\,^2F_{5/2}$	-0.953	2.273E+09
7	572.563	174653	572.572	-0.009	$4p^3$	$^2P_{3/2}$	$4p^24d\,(^1D)\,^2D_{5/2}$	-0.231	1.182E+10
25	573.467	174378	573.459	0.008	$4s4p^2$	$^4P_{1/2}$	$4s4p4d\,(^3P)\,^4F_{3/2}$	-2.163	1.394E+08
15	575.181	173858	575.185	-0.004	$4p^3$	$^2D_{5/2}$	$4p^24d\,(^3P)\,^2P_{3/2}$	0.021	2.168E+10
100	576.594[d]	173432	576.593	0.001	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\,(^3P)\,^4F_{5/2}$	-1.507	6.223E+08
30	578.602[d]	172830.4	578.601	0.001	$4s4p^2$	$^4P_{1/2}$	$4p^3\ \ ^2P_{3/2}$	-1.923	2.380E+08
90	579.943[d]	172430.7	579.949	-0.006	$4s4p^2$	$^2D_{3/2}$	$4s4p4d\,(^3P)\,^2D_{5/2}$	0.228	3.362E+10
100	581.581[d]	171945.1	581.576	0.005	$4s4p^2$	$^2D_{3/2}$	$4s4p4d\,(^3P)\,^2D_{3/2}$	0.475	5.909E+10
30	581.719	171904.3	581.703	0.016	$4s4p^2$	$^4P_{3/2}$	$4s4p4d\,(^3P)\,^4F_{3/2}$	-2.292	1.006E+08
65	582.408[d]	171701	582.394	0.014	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\,(^3P)\,^4F_{7/2}$	-1.113	1.514E+09
100	582.408[d]	171701	582.412	-0.004	$4s4p^2$	$^2D_{5/2}$	$4s4p4d\,(^3P)\,^2D_{5/2}$	0.436	5.387E+10
50	583.288[d]	171441.9	583.285	0.003	$4s4p^2$	$^2D_{3/2}$	$4s^24f\ \ ^2F_{5/2}$	-0.612	4.805E+09
80	584.053[d]	171217.3	584.054	-0.001	$4s4p^2$	$^2D_{5/2}$	$4s4p4d\,(^3P)\,^2D_{3/2}$	-0.530	5.793E+09
70	584.733[d]	171018.2	584.725	0.008	$4s4p^2$	$^2D_{5/2}$	$4s^24f\ \ ^2F_{7/2}$	0.310	3.987E+10
40	585.565[d]	170775.2	585.565	0	$4s4p^2$	$^2S_{1/2}$	$4s4p4d\,(^3P)\,^2P_{1/2}$	-0.579	5.122E+09
95	585.781[d]	170712.3	585.777	0.004	$4s4p^2$	$^2D_{5/2}$	$4s^24f\ \ ^2F_{5/2}$	0.185	2.986E+10
30	586.996[d]	170358.9	586.995	0.001	$4s4p^2$	$^4P_{3/2}$	$4p^3\ \ ^2P_{3/2}$	-1.580	5.090E+08
95	587.538[d]	170201.8	587.538	0	$4s4p^2$	$^2S_{1/2}$	$4s4p4d\,(^3P)\,^2P_{3/2}$	0.460	5.553E+10
25	591.235[d]	169137.5	591.226	0.009	$4s4p^2$	$^2P_{3/2}$	$4s4p5s\,(^3P)\,^2P_{3/2}$	-2.199	1.209E+08
10	591.752	168989.7	591.752	0	$4p^3$	$^2D_{3/2}$	$4s4p4f\,(^3P)\,^2D_{3/2}$	-0.488	6.203E+09
20	593.096[d]	168606.8	593.099	-0.003	$4s4p^2$	$^4P_{5/2}$	$4s4p4d\,(^3P)\,^4F_{3/2}$	-2.950	2.125E+07
40	594.886[d]	168099.4	594.883	0.003	$4s4p^2$	$^2S_{1/2}$	$4s4p5s\,(^3P)\,^4P_{3/2}$	-0.690	3.838E+09
20	598.601[d]	167056.2	598.601	0	$4s4p^2$	$^4P_{5/2}$	$4p^3\ \ ^2P_{3/2}$	-2.166	1.266E+08
23	604.870	165324.8	604.871	-0.001	$4p^3$	$^2D_{5/2}$	$4s4p4f\,(^3P)\,^2D_{5/2}$	-0.168	1.245E+10
22	611.696	163479.9	611.700	-0.004	$4p^3$	$^2D_{5/2}$	$4s4p5p\,(^1P)\,^2P_{3/2}$	-0.836	2.607E+09
40	616.163[d]	162294.7	616.169	-0.006	$4s4p^2$	$^2D_{3/2}$	$4s4p4d\,(^3P)\,^4D_{3/2}$	-1.395	7.096E+08
75	616.899[d]	162101.1	616.899	0	$4s4p^2$	$^2P_{1/2}$	$4s4p4d\,(^3P)\,^2P_{1/2}$	-0.013	1.700E+10
20	619.173[d]	161505.8	619.171	0.002	$4s4p^2$	$^2D_{3/2}$	$4s4p4d\,(^3P)\,^4P_{5/2}$	-2.261	9.545E+07

95	621.034[d]	161021.8	621.034	0	$4s^24p$	$^2P_{1/2}$	$4s4p^2$	$^2P_{3/2}$	-0.176	1.152E+10
60	621.980[d]	160776.9	621.980	0	$4s4p^2$	$^2D_{5/2}$	$4s4p4d\ (^3P)$	$^4P_{5/2}$	-0.997	1.739E+09
10	622.778	160570.9	622.772	0.006	$4s^25p$	$^2P_{1/2}$	$4s4p5p\ (^1P)$	$^2S_{1/2}$	-0.628	4.026E+09
5	625.727[d]	159814.1	625.724	0.003	$4s4p^2$	$^4P_{3/2}$	$4s^25p$	$^2P_{3/2}$	-2.915	2.070E+07
10	627.443[d]	159377	627.433	0.01	$4s^24d$	$^2D_{3/2}$	$4s^26p$	$^2P_{3/2}$	-1.448	6.039E+08
60	627.944[d]	159249.9	627.949	-0.005	$4s4p^2$	$^2P_{3/2}$	$4s4p4d\ (^3P)$	$^2P_{1/2}$	-0.744	3.049E+09
33	629.749	158793.4	629.760	-0.011	$4s^25p$	$^2P_{3/2}$	$4s4p5p\ (^1P)$	$^2S_{1/2}$	-0.108	1.305E+10
40	629.902[d]	158754.9	629.907	-0.005	$4s^24d$	$^2D_{5/2}$	$4s^26p$	$^2P_{3/2}$	-0.662	3.663E+09
60	630.221[d]	158674.5	630.218	0.003	$4s4p^2$	$^2P_{3/2}$	$4s4p4d\ (^3P)$	$^2P_{3/2}$	-0.011	1.637E+10
30	631.536[d]	158344.1	631.538	-0.002	$4s^24d$	$^2D_{3/2}$	$4s^26p$	$^2P_{1/2}$	-1.007	1.646E+09
90	632.230[d]	158170.3	632.234	-0.004	$4s^24p$	$^2P_{1/2}$	$4s4p^2$	$^2P_{1/2}$	-0.208	1.033E+10
30	638.678[d]	156573.4	638.677	0.001	$4s4p^2$	$^2P_{3/2}$	$4s4p5s\ (^3P)$	$^4P_{3/2}$	-1.062	1.417E+09
30	638.929[d]	156511.9	638.930	-0.001	$4s4p^2$	$^4P_{5/2}$	$4s^25p$	$^2P_{3/2}$	-2.206	1.015E+08
100	645.439[d]	154933.3	645.432	0.007	$4s^24p$	$^2P_{3/2}$	$4s4p^2$	$^2P_{3/2}$	0.494	4.993E+10
10	647.470	154447.3	647.463	0.007	$4s4p4d\ (^3P)$	$^4F_{7/2}$	$4p^24d\ (^3P)$	$^4D_{7/2}$	-0.263	8.726E+09
16	650.797	153657.7	650.819	-0.022	$4s4p4d\ (^3P)$	$^4F_{5/2}$	$4p^24d\ (^3P)$	$^4D_{5/2}$	-0.250	8.943E+09
50	655.433	152570.9	655.433	0	$4s^25p$	$^2P_{1/2}$	$4s4p5p\ (^1P)$	$^2D_{3/2}$	0.043	1.723E+10
100	657.532[d]	152083.9	657.538	-0.006	$4s^24p$	$^2P_{3/2}$	$4s4p^2$	$^2P_{1/2}$	0.010	1.581E+10
70	658.215[d]	151926	658.215	0	$4s^25s$	$^2S_{1/2}$	$4s4p5s\ (^1P)$	$^2P_{3/2}$	0.386	3.742E+10
80	658.324	151900.9	658.319	0.005	$4s^25p$	$^2P_{3/2}$	$4s4p5p\ (^1P)$	$^2D_{5/2}$	0.539	5.329E+10
60	658.777[d]	151796.4	658.775	0.002	$4s^25s$	$^2S_{1/2}$	$4s4p5s\ (^1P)$	$^2P_{1/2}$	0.085	1.870E+10
65	658.940[d]	151758.9	658.934	0.006	$4s^24d$	$^2D_{3/2}$	$4s4p4d\ (^1P)$	$^2P_{3/2}$	0.104	1.953E+10
55	661.669[d]	151133	661.663	0.006	$4s^24d$	$^2D_{5/2}$	$4s4p4d\ (^1P)$	$^2P_{3/2}$	0.072	1.801E+10
70	661.998[d]	151057.9	661.996	0.002	$4s^24d$	$^2D_{5/2}$	$4s4p4d\ (^1P)$	$^2D_{5/2}$	0.465	4.418E+10
63	662.957	150839.3	662.955	0.002	$4s^25p$	$^2P_{1/2}$	$4s4p5p\ (^1P)$	$^2P_{3/2}$	0.147	2.135E+10
65	663.153	150794.8	663.177	-0.024	$4s^25p$	$^2P_{3/2}$	$4s4p5p\ (^1P)$	$^2D_{3/2}$	0.137	2.090E+10
70	663.810[d]	150645.5	663.814	-0.004	$4s^24d$	$^2D_{3/2}$	$4s4p4d\ (^1P)$	$^2P_{1/2}$	0.068	1.775E+10
65	665.137	150345	665.135	0.002	$4s^25p$	$^2P_{1/2}$	$4s4p5p\ (^1P)$	$^2P_{1/2}$	-0.026	1.415E+10
50	665.478[d]	150267.9	665.481	-0.003	$4s^24d$	$^2D_{3/2}$	$4s4p4d\ (^1P)$	$^2D_{3/2}$	-0.116	1.151E+10
75	666.535[d]	150029.6	666.541	-0.006	$4s4p^2$	$^4P_{1/2}$	$4p^3$	$^4S_{3/2}$	-0.211	9.245E+09
40	666.962	149933.6	666.964	-0.002	$4s4p4d\ (^3P)$	$^4F_{7/2}$	$4p^24d\ (^3P)$	$^4F_{9/2}$	-0.181	9.832E+09
70	668.258[d]	149642.8	668.265	-0.007	$4s^24d$	$^2D_{5/2}$	$4s4p4d\ (^1P)$	$^2D_{3/2}$	0.126	1.989E+10
7	668.698	149544.3	668.700	-0.002	$4s4p4d\ (^3P)$	$^4F_{3/2}$	$4p^24d\ (^3P)$	$^4F_{3/2}$	-0.016	1.398E+10
100	668.917[d]	149495.4	668.917	0	$4s^24p$	$^2P_{1/2}$	$4s4p^2$	$^2S_{1/2}$	-0.062	1.295E+10
5	669.638	149334.4	669.637	0.001	$4s4p4d\ (^3P)$	$^4F_{5/2}$	$4p^24d\ (^3P)$	$^4F_{7/2}$	-0.229	8.742E+09
35	670.885	149056.8	670.880	0.005	$4s^25p$	$^2P_{3/2}$	$4s4p5p\ (^1P)$	$^2P_{3/2}$	0.032	1.598E+10
5	671.644	148888.4	671.628	0.016	$4p^3$	$^2P_{3/2}$	$4p^24d\ (^3P)$	$^2P_{3/2}$	-0.282	7.945E+09
15	673.111	148563.9	673.111	0	$4s^25p$	$^2P_{3/2}$	$4s4p5p\ (^1P)$	$^2P_{1/2}$	-0.500	4.630E+09

80	676.403^{d}	147840.9	676.407	-0.004	$4s^24d$	$^2D_{3/2}$	$4s4p4d$ (^1P)	$^2F_{5/2}$	0.886	1.220E+11
25	676.773	147760	676.777	-0.004	$4s4p4d$ (^3P)	$^4F_{7/2}$	$4p^24d$ (^3P)	$^4F_{7/2}$	0.371	3.399E+10
95	677.693^{d,B}	147559	677.705	-0.012	$4s4p^2$	$^4P_{3/2}$	$4p^3$	$^4S_{3/2}$	0.089	1.781E+10
10	678.485^{d}	147387.2	678.487	-0.002	$4s4p^2$	$^2D_{5/2}$	$4s4p4d$ (^3P)	$^4F_{7/2}$	-2.265	7.896E+07
25	678.995	147276.5	679.002	-0.007	$4s4p4d$ (^3P)	$^4F_{7/2}$	$4p^24d$ (^3P)	$^4F_{5/2}$	-0.012	1.374E+10
10	679.279^{d}	147214.9	679.283	-0.004	$4s^24d$	$^2D_{5/2}$	$4s4p4d$ (^1P)	$^2F_{5/2}$	-0.510	4.468E+09
3	681.76	146679	681.779	-0.019	$4s^24f$	$^2F_{5/2}$	$4p^24d$ (^1D)	$^2D_{5/2}$	-0.126	1.073E+10
30	681.891^{d}	146651	681.892	-0.001	$4s4p^2$	$^4P_{1/2}$	$4p^3$	$^2D_{3/2}$	-1.544	4.103E+08
85	682.413^{d,S}	146539	682.404	0.009	$4s4p^2$	$^2D_{3/2}$	$4s4p4d$ (^3P)	$^4F_{5/2}$	-3.124	1.075E+07
85	682.413^{d,S}	146539	682.414	-0.001	$4s^24d$	$^2D_{5/2}$	$4s4p4d$ (^1P)	$^2F_{7/2}$	1.035	1.551E+11
70	685.821	145810.6	685.817	0.004	$4s4p^2$	$^2D_{5/2}$	$4s4p4d$ (^3P)	$^4F_{5/2}$	-1.852	1.992E+08
15	686.411	145685.3	686.395	0.016	$4s4p4d$ (^3P)	$^2D_{5/2}$	$4p^24d$ (^1D)	$^2D_{5/2}$	-0.432	5.148E+09
45	688.005^{d}	145347.8	688.005	0	$4s4p^2$	$^2S_{1/2}$	$4s4p4d$ (^3P)	$^2D_{3/2}$	-1.083	1.164E+09
45	689.568^{d}	145018.3	689.573	-0.005	$4s4p^2$	$^2D_{3/2}$	$4s4p4d$ (^3P)	$^4F_{3/2}$	-1.598	3.545E+08
20	691.019	144713.8	691.017	0.002	$4s4p4d$ (^3P)	$^4P_{5/2}$	$4p^24d$ (^3P)	$^4P_{5/2}$	-0.099	1.114E+10
10	693.050^{d}	144289.7	693.059	-0.009	$4s4p^2$	$^2D_{5/2}$	$4s4p4d$ (^3P)	$^4F_{3/2}$	-2.475	4.667E+07
71	693.218^{d}	144254.8	693.223	-0.005	$4s4p^2$	$^4P_{5/2}$	$4p^3$	$^4S_{3/2}$	0.247	2.446E+10
35	693.573^{d}	144180.9	693.581	-0.008	$4s4p^2$	$^4P_{3/2}$	$4p^3$	$^2D_{3/2}$	-1.498	4.396E+08
13	694.79	143928.4	694.794	-0.004	$4s4p4d$ (^3P)	$^4D_{3/2}$	$4p^24d$ (^3P)	$^4P_{5/2}$	-0.096	1.108E+10
13	695.664	143747.6	695.667	-0.003	$4p^3$	$^2P_{1/2}$	$4s4p4f$ (^3P)	$^2D_{3/2}$	-0.139	1.003E+10
75	697.026^{d}	143466.7	697.022	0.004	$4s4p^2$	$^2D_{3/2}$	$4p^3$	$^2P_{3/2}$	-0.902	1.720E+09
100	697.312^{d}	143407.8	697.309	0.003	$4s^24p$	$^2P_{3/2}$	$4s4p^2$	$^2S_{1/2}$	-1.207	8.527E+08
85	700.578^{d}	142739.3	700.584	-0.006	$4s4p^2$	$^2D_{5/2}$	$4p^3$	$^2P_{3/2}$	0.074	1.617E+10
90	701.599^{d}	142531.6	701.605	-0.006	$4s4p^2$	$^2D_{3/2}$	$4p^3$	$^2P_{1/2}$	-0.140	9.844E+09
30	703.350^{d}	142176.7	703.343	0.007	$4s^24d$	$^2D_{3/2}$	$4s4p5s$ (^3P)	$^2P_{3/2}$	-1.195	8.629E+08
20	703.768^{d}	142092.3	703.774	-0.006	$4s4p^2$	$^4P_{5/2}$	$4p^3$	$^2D_{5/2}$	-2.038	1.232E+08
30	706.460^{d}	141550.8	706.453	0.007	$4s^24d$	$^2D_{5/2}$	$4s4p5s$ (^3P)	$^2P_{3/2}$	-1.152	9.442E+08
20	708.948	141054.1	708.925	0.023	$4s4p4d$ (^3P)	$^4P_{5/2}$	$4p^24d$ (^3P)	$^4D_{7/2}$	0.163	1.945E+10
66	709.843^{d}	140876.2	709.843	0	$4s4p^2$	$^4P_{5/2}$	$4p^3$	$^2D_{3/2}$	-1.059	1.152E+09
5	712.004^{d}	140448.6	711.989	0.015	$4s4p^2$	$^2P_{3/2}$	$4s4p4d$ (^3P)	$^2F_{5/2}$	-2.284	6.852E+07
40	712.437	140363.3	712.431	0.006	$4s4p4d$ (^3P)	$^4D_{7/2}$	$4p^24d$ (^3P)	$^4P_{5/2}$	0.231	2.236E+10
38	712.447	140361.3	712.456	-0.009	$4p^3$	$^2P_{3/2}$	$4s4p4f$ (^3P)	$^2D_{5/2}$	-0.027	1.244E+10
5	714.831	139893.2	714.834	-0.003	$4s4p4d$ (^3P)	$^4P_{3/2}$	$4p^24d$ (^3P)	$^4P_{5/2}$	-0.584	3.411E+09
5	716.603	139547.3	716.608	-0.005	$4s4p4d$ (^3P)	$^4F_{7/2}$	$4s^26g$ (^1S)	$^2G_{7/2}$	-2.167	8.793E+07
20	717.555^{d}	139362.1	717.570	-0.015	$4s^24d$	$^2D_{3/2}$	$4s4p5s$ (^3P)	$^2P_{1/2}$	-0.960	1.417E+09

10	725.163	137900	725.162	0.001	4s4p4d (^{3}P) $^4D_{3/2}$	$4p^2$4d (^{3}P) $^4D_{5/2}$	-0.221	7.673E+09
8	729.68	137046.4	729.677	0.003	4s4p4d (^{3}P) $^4F_{5/2}$	4s4p4f (^{3}P) $^2G_{7/2}$	-1.083	1.041E+09
50	731.465	136711.9	731.481	-0.016	4s4p4d (^{3}P) $^4D_{7/2}$	$4p^2$4d (^{3}P) $^4D_{7/2}$	0.051	1.409E+10
60	731.669[d]	136673.8	731.670	-0.001	$4s4p^2$ $^2P_{1/2}$	4s4p4d (^{3}P) $^2D_{3/2}$	-0.725	2.351E+09
5	732.649	136491	732.639	0.01	4s4p4d (^{3}P) $^4P_{5/2}$	$4p^2$4d (^{1}D) $^2F_{7/2}$	0.238	2.144E+10
8	732.762	136470	732.764	-0.002	4s4p4d (^{3}P) $^4F_{3/2}$	4s4p5p (^{1}P) $^2P_{1/2}$	-1.182	1.179E+09
60	733.812[B]	136274.7	733.805	0.007	4s4p4d (^{3}P) $^4D_{5/2}$	$4p^2$4d (^{3}P) $^4D_{7/2}$	0.035	1.352E+10
15	736.954[d]	135693.7	736.951	0.003	$4s4p^2$ $^2S_{1/2}$	4s4p4d (^{3}P) $^4D_{3/2}$	-2.701	2.443E+07
50	744.209[B]	134370.9	744.219	-0.01	4s4p4d (^{3}P) $^4P_{5/2}$	$4p^2$4d (^{3}P) $^4F_{7/2}$	0.443	3.321E+10
20	744.395	134337.3	744.395	0	4s4p4d (^{3}P) $^4D_{7/2}$	$4p^2$4d (^{3}P) $^4D_{5/2}$	-0.217	7.340E+09
40	744.572[d]	134305.3	744.581	-0.009	$4s4p^2$ $^2P_{3/2}$	4s4p4d (^{3}P) $^2D_{5/2}$	-0.756	2.112E+09
40	746.811	133902.7	746.803	0.008	4s4p4d (^{3}P) $^4D_{5/2}$	$4p^2$4d (^{3}P) $^4D_{5/2}$	0.214	1.971E+10
10	746.921	133883	746.911	0.01	4s4p4d (^{3}P) $^4P_{5/2}$	$4p^2$4d (^{3}P) $^4F_{5/2}$	-0.197	7.411E+09
40	747.023	133864.7	747.019	0.004	4s4p4d (^{3}P) $^4P_{3/2}$	$4p^2$4d (^{3}P) $^4D_{5/2}$	0.103	1.529E+10
40	747.040[d]	133861.6	747.049	-0.009	$4s^2$5s $^2S_{1/2}$	$4s^2$6p $^2P_{3/2}$	-0.714	2.311E+09
40	747.261	133822.1	747.266	-0.005	$4s4p^2$ $^2P_{3/2}$	4s4p4d (^{3}P) $^2D_{3/2}$	-1.226	7.115E+08
60	750.088[d]	133317.7	750.090	-0.002	$4s4p^2$ $^2P_{3/2}$	$4s^2$4f $^2F_{5/2}$	-0.918	1.432E+09
30	750.909[W]	133171.9	750.898	0.011	4s4p4d (^{3}P) $^4F_{3/2}$	4s4p4f (^{3}P) $^4D_{5/2}$	-0.905	1.517E+09
60	751.092	133139.5	751.094	-0.002	4s4p4d (^{3}P) $^4F_{5/2}$	4s4p4f (^{3}P) $^4D_{7/2}$	0.739	6.524E+10
60	751.092	133139.5	751.096	-0.004	4s4p4d (^{3}P) $^4F_{7/2}$	4s4p4f (^{3}P) $^4G_{9/2}$	0.837	8.068E+10
45	751.321	133098.9	751.326	-0.005	4s4p4d (^{3}P) $^4D_{3/2}$	$4p^2$4d (^{3}P) $^4F_{5/2}$	0.430	3.098E+10
10	752.325[d]	132921.3	752.315	0.01	$4s4p^2$ $^2D_{3/2}$	$4s^2$5p $^2P_{3/2}$	-2.029	1.105E+08
30	752.870[d]	132825.1	752.875	-0.005	$4s^2$5s $^2S_{1/2}$	$4s^2$6p $^2P_{1/2}$	-0.934	1.367E+09
10	753.386	132734.1	753.398	-0.012	$4s^2$4f $^2F_{5/2}$	$4p^2$4d (^{1}D) $^2G_{7/2}$	-0.487	3.812E+09
70	755.930[d]	132287.4	755.933	-0.003	$4s^2$4d $^2D_{3/2}$	4s4p4d (^{3}P) $^2P_{1/2}$	-3.151	8.238E+06
5	756.044	132267.4	756.040	0.004	4s4p4d (^{3}P) $^4D_{3/2}$	$4p^2$4d (^{3}P) $^4F_{3/2}$	-0.214	6.910E+09
70	756.479	132191.4	756.470	0.009	4s4p4d (^{3}P) $^4D_{7/2}$	$4p^2$4d (^{3}P) $^4F_{9/2}$	0.769	6.796E+10
75	756.479[d]	132191.4	756.467	0.012	$4s4p^2$ $^2D_{5/2}$	$4s^2$5p $^2P_{3/2}$	-0.945	1.327E+09
10	759.202	131717.3	759.199	0.003	4s4p4d (^{3}P) $^4D_{1/2}$	$4p^2$4d (^{3}P) $^4F_{3/2}$	0.261	2.042E+10
5	759.235[d]	131711.5	759.225	0.01	$4s^2$4d $^2D_{3/2}$	4s4p4d (^{3}P) $^2P_{3/2}$	-1.770	1.964E+08
5	759.238	131711	759.243	-0.005	4s4p4d (^{3}P) $^4D_{5/2}$	$4p^2$4d (^{1}D) $^2F_{7/2}$	-0.174	7.734E+09
20	760.075	131566	760.088	-0.013	4s4p4d (^{3}P) $^4F_{7/2}$	4s4p4f (^{3}P) $^4D_{7/2}$	-0.101	9.062E+09
65	762.538[d]	131141	762.536	0.002	$4s4p^2$ $^2D_{3/2}$	$4s^2$5p $^2P_{1/2}$	-1.195	7.330E+08
10	762.849[d]	131087.5	762.850	-0.001	$4s^2$4d $^2D_{5/2}$	4s4p4d (^{3}P) $^2P_{3/2}$	-2.022	1.088E+08
40	768.417[B]	130137.7	768.427	-0.01	4s4p4d (^{3}P) $^2D_{5/2}$	$4p^2$4d (^{3}P) $^4D_{7/2}$	-0.257	6.224E+09

35	768.780	130076.2	768.788	-0.008	4s4p4d (^{3}P) $^4F_{7/2}$	4s4p4f (^{3}P) $^4D_{5/2}$	-0.219	7.024E+09
5	769.259	129995.2	769.278	-0.019	4s4p4d (^{3}P) $^4D_{5/2}$	4p^{2}4d (^{1}D) $^2F_{5/2}$	-0.653	2.516E+09
3	769.511	129952.7	769.508	0.003	4s4p4d (^{3}P) $^4P_{3/2}$	4p^{2}4d (^{1}D) $^2F_{5/2}$	-0.671	2.415E+09
8	771.447	129626.5	771.451	-0.004	4p^3 $^2D_{5/2}$	4s4p5p (^{3}P) $^2D_{5/2}$	-0.856	1.584E+09
10	771.534^d	129611.9	771.535	-0.001	4s^{2}4d $^2D_{3/2}$	4s4p5s (^{3}P) $^4P_{3/2}$	-4.053	9.912E+05
10	771.700	129584	771.687	0.013	4s4p4d (^{3}P) $^4D_{5/2}$	4p^{2}4d (^{3}P) $^4F_{7/2}$	0.331	2.381E+10
15	772.096	129517.6	772.105	-0.009	4s4p4d (^{3}P) $^4D_{1/2}$	4p^{2}4d (^{3}P) $^2P_{3/2}$	-0.776	1.927E+09
10	775.262^d	128988.7	775.279	-0.017	4s^{2}4d $^2D_{5/2}$	4s4p5s (^{3}P) $^4P_{3/2}$	-2.119	8.441E+07
10	780.943	128050.3	780.939	0.004	4p^3 $^2D_{3/2}$	4s4p5p (^{3}P) $^2D_{3/2}$	-1.155	7.714E+08
10	784.256	127509.4	784.260	-0.004	4s^{2}5p $^2P_{1/2}$	4s^{2}7s $^2S_{1/2}$	-1.133	7.983E+08
3	786.958	127071.6	786.960	-0.002	4p^3 $^2D_{3/2}$	4s4p5p (^{3}P) $^4S_{3/2}$	-1.410	4.199E+08
10	787.268^d	127021.5	787.276	-0.008	4s4p^2 $^2P_{1/2}$	4s4p4d (^{3}P) $^4D_{3/2}$	-2.949	1.210E+07
5	792.67	126155.9	792.669	0.001	4s4p4d (^{3}P) $^4P_{5/2}$	4s^{2}6g (^{1}S) $^2G_{7/2}$	-2.521	3.184E+07
27	795.376	125726.7	795.373	0.003	4s^{2}5p $^2P_{3/2}$	4s^{2}7s $^2S_{1/2}$	-0.741	1.914E+09
5	796.204	125596	796.194	0.01	4s4p4d (^{3}P) $^2F_{5/2}$	4p^{2}4d (^{1}D) $^2G_{7/2}$	0.207	1.692E+10
5	804.283	124334.3	804.281	0.002	4s4p4d (^{3}P) $^2D_{3/2}$	4p^{2}4d (^{1}D) $^2F_{5/2}$	-0.048	9.250E+09
20	810.492^d	123381.8	810.498	-0.006	4s4p^2 $^2P_{3/2}$	4s4p4d (^{3}P) $^4P_{5/2}$	-2.120	7.688E+07
95	813.693^d	122896.5	813.693	0	4s^{2}4p $^2P_{1/2}$	4s4p^2 $^2D_{3/2}$	-0.496	3.205E+09
10	815.953	122556.1	815.956	-0.003	4s4p4d (^{3}P) $^4D_{7/2}$	4s^{2}6g (^{1}S) $^2G_{9/2}$	-1.160	6.887E+08
20	828.142	120752.2	828.149	-0.007	4p^3 $^2D_{5/2}$	4s4p5p (^{3}P) $^4P_{3/2}$	-0.997	9.810E+08
17	828.748^d	120663.9	828.741	0.007	4s4p^2 $^2D_{3/2}$	4p^3 $^4S_{3/2}$	-1.865	1.330E+08
91	833.762^{d,B}	119938.3	833.781	-0.019	4s4p^2 $^2D_{5/2}$	4p^3 $^4S_{3/2}$	-2.321	4.602E+07
5	833.860	119924.2	833.850	0.01	4p^3 $^2D_{3/2}$	4s4p5p (^{3}P) $^4P_{1/2}$	-1.399	3.812E+08
33	843.223	118592.6	843.229	-0.006	4p^3 $^2D_{3/2}$	4s4p5p (^{3}P) $^2P_{1/2}$	-0.910	1.157E+09
85	843.863^d	118502.6	843.865	-0.002	4s4p^2 $^2D_{3/2}$	4p^3 $^2D_{5/2}$	-1.270	5.041E+08
95	849.092^d	117772.9	849.092	0	4s4p^2 $^2D_{5/2}$	4p^3 $^2D_{5/2}$	-0.207	5.767E+09
5	849.596	117703	849.588	0.008	4s4p4d (^{3}P) $^2F_{5/2}$	4p^{2}4d (^{1}D) $^2F_{5/2}$	0.093	1.149E+10
15	849.975	117650.5	849.989	-0.014	4p^3 $^2D_{5/2}$	4s4p5p (^{3}P) $^2P_{3/2}$	-0.701	1.831E+09
100	850.785^d	117538.5	850.781	0.004	4s^{2}4p $^2P_{3/2}$	4s4p^2 $^2D_{5/2}$	-0.349	4.110E+09
30	851.017^d	117506.5	851.013	0.004	4s^{2}4d $^2D_{5/2}$	4s4p4d (^{3}P) $^2F_{7/2}$	-1.050	8.215E+08
85	852.602^d	117288	852.606	-0.004	4s4p^2 $^2D_{3/2}$	4p^3 $^2D_{3/2}$	-0.522	2.762E+09
80	855.664^d	116868.3	855.662	0.002	4s4p^2 $^2S_{1/2}$	4p^3 $^2P_{3/2}$	-0.800	1.439E+09
90	856.096^d	116809.3	856.094	0.002	4s^{2}4p $^2P_{3/2}$	4s4p^2 $^2D_{3/2}$	-1.889	1.171E+08
30	857.199	116659	857.179	0.02	4s^{2}4f $^2F_{7/2}$	4s^{2}6g (^{1}S) $^2G_{9/2}$	0.096	1.127E+10
30	857.199^d	116659	857.201	-0.002	4s^{2}5s $^2S_{1/2}$	4s4p5s (^{3}P) $^2P_{3/2}$	-1.352	4.046E+08

80	857.936[d]	116558.8	857.941	-0.005	$4s4p^2$	$^2D_{5/2}$	$4p^3$	$^2D_{3/2}$	-0.906	1.129E+09
68	860.437	116220	860.439	-0.002	$4s^24f$	$^2F_{5/2}$	$4s^26g\ (^1S)\ ^2G_{7/2}$		-0.150	6.335E+09
2	861.819	116033.6	861.829	-0.01	$4p^3$	$^2D_{3/2}$	$4s4p5p\ (^3P)\ ^4D_{3/2}$		-2.509	2.798E+07
15	862.584[d]	115930.7	862.578	0.006	$4s4p^2$	$^2S_{1/2}$	$4p^3$	$^2P_{1/2}$	-2.907	1.110E+07
8	862.731	115911	862.720	0.011	$4s^24f$	$^2F_{7/2}$	$4s^26g\ (^1S)\ ^2G_{7/2}$		-1.308	4.395E+08
6	870.855	114829.7	870.859	-0.004	$4s4p4d\ (^3P)\ ^2F_{7/2}$		$4p^24d\ (^3P)\ ^4F_{9/2}$		-0.395	3.514E+09
7	870.95	114817.2	870.947	0.003	$4p^3$	$^2D_{5/2}$	$4s4p5p\ (^3P)\ ^4D_{3/2}$		-1.084	7.273E+08
3	871.222	114781.3	871.239	-0.017	$4s4p4d\ (^3P)\ ^2F_{7/2}$		$4p^24d\ (^1D)\ ^2F_{7/2}$		0.018	9.107E+09
5	880.661	113551.1	880.665	-0.004	$4p^3$	$^2P_{1/2}$	$4s4p5p\ (^3P)\ ^2S_{1/2}$		-1.213	5.260E+08
65	881.142[d]	113489.1	881.136	0.006	$4s^24d$	$^2D_{3/2}$	$4s4p4d\ (^3P)\ ^2F_{5/2}$		-0.995	8.707E+08
3	881.917	113389.4	881.907	0.01	$4s4p4d\ (^3P)\ ^4D_{5/2}$		$4s4p4f\ (^3P)\ ^4D_{7/2}$		-1.369	3.625E+08
3	884.355	113076.8	884.369	-0.014	$4s^24f$	$^2F_{7/2}$	$4s4p5p\ (^1P)\ ^2D_{5/2}$		-0.868	1.175E+09
10	886.034[d]	112862.5	886.023	0.011	$4s^24d$	$^2D_{5/2}$	$4s4p4d\ (^3P)\ ^2F_{5/2}$		-1.377	3.566E+08
12	888.001	112612.5	887.994	0.007	$4p^3$	$^2P_{3/2}$	$4s4p5p\ (^3P)\ ^2S_{1/2}$		-0.916	1.028E+09
5	890.720	112268.7	890.714	0.006	$4s^24f$	$^2F_{5/2}$	$4s4p5p\ (^1P)\ ^2D_{3/2}$		-1.257	4.681E+08
10	893.910[B]	111868	893.950	-0.04	$4s4p4d\ (^3P)\ ^4P_{3/2}$		$4s4p4f\ (^3P)\ ^4D_{5/2}$		-0.331	4.045E+09
10	899.626	111157.3	899.616	0.01	$4s4p4d\ (^3P)\ ^2D_{5/2}$		$4s4p4f\ (^3P)\ ^2G_{7/2}$		-0.974	8.762E+08
50	916.707	109086.1	916.713	-0.006	$4s4p4d\ (^3P)\ ^2F_{5/2}$		$4s^26g\ (^1S)\ ^2G_{7/2}$		-0.278	4.166E+09
50	924.269[d]	108193.6	924.261	0.008	$4s4p^2$	$^2P_{1/2}$	$4p^3$	$^2P_{3/2}$	-2.552	2.187E+07
5	928.504	107700.1	928.503	0.001	$4s4p4d\ (^3P)\ ^2F_{5/2}$		$4s4p4f\ (^3P)\ ^2D_{3/2}$		-0.599	1.953E+09
75	931.597[d]	107342.6	931.604	-0.007	$4s^24d$	$^2D_{3/2}$	$4s4p4d\ (^3P)\ ^2D_{5/2}$		-0.464	2.643E+09
80	932.331[d]	107258	932.337	-0.006	$4s4p^2$	$^2P_{1/2}$	$4p^3$	$^2P_{1/2}$	-0.650	1.719E+09
20	935.806[d]	106859.8	935.811	-0.005	$4s^24d$	$^2D_{3/2}$	$4s4p4d\ (^3P)\ ^2D_{3/2}$		-1.599	1.925E+08
5	936.621[d]	106766.8	936.616	0.005	$4s^25s$	$^2S_{1/2}$	$4s4p4d\ (^3P)\ ^2P_{1/2}$		-2.051	6.754E+07
20	937.077[d]	106714.8	937.067	0.01	$4s^24d$	$^2D_{5/2}$	$4s4p4d\ (^3P)\ ^2D_{5/2}$		-3.128	5.658E+06
80	940.253[d]	106354.4	940.244	0.009	$4s^24d$	$^2D_{3/2}$	$4s^24f$	$^2F_{5/2}$	-0.91	3.980E+09
10	941.678[d]	106193.4	941.674	0.004	$4s^25s$	$^2S_{1/2}$	$4s4p4d\ (^3P)\ ^2P_{3/2}$		-1.860	1.037E+08
100	943.079[d]	106035.7	943.069	0.01	$4s^24d$	$^2D_{5/2}$	$4s^24f$	$^2F_{7/2}$	0.081	9.032E+09
40	945.815[d]	105728.9	945.810	0.005	$4s^24d$	$^2D_{5/2}$	$4s^24f$	$^2F_{5/2}$	-1.073	6.303E+08
80	949.292[d]	105341.7	949.289	0.003	$4s4p^2$	$^2P_{3/2}$	$4p^3$	$^2P_{3/2}$	-0.396	2.969E+09
15	950.652	105191	950.647	0.005	$4s4p4d\ (^3P)\ ^2F_{7/2}$		$4s^26g\ (^1S)\ ^2G_{9/2}$		0.356	1.660E+10
60	952.287	105010.4	952.285	0.002	$4s4p4d\ (^3P)\ ^2F_{5/2}$		$4s4p4f\ (^3P)\ ^2G_{7/2}$		0.563	2.694E+10
5	955.530	104654	955.516	0.014	$4s4p4d\ (^3P)\ ^4F_{7/2}$		$4s^25g\ (^1S)\ ^2G_{9/2}$		-1.963	7.961E+07
5	956.532[d]	104544.3	956.549	-0.017	$4s4p^2$	$^2S_{1/2}$	$4s^25p$	$^2P_{1/2}$	-4.523	2.180E+05
60	957.808[d]	104405.1	957.809	-0.001	$4s4p^2$	$^2P_{3/2}$	$4p^3$	$^2P_{1/2}$	-1.277	3.852E+08

10	960.677[d]	104093.3	960.686	-0.009	$4s^25s$ $^2S_{1/2}$	$4s4p5s\,(^3P)\,^4P_{3/2}$	-1.600	1.816E+08
5	993.966	100607.1	993.970	-0.004	$4s4p4d\,(^3P)\,^2F_{7/2}$	$4s4p4f\,(^3P)\,^2D_{5/2}$	-0.448	2.400E+09
10	998.579[d]	100142.3	998.573	0.006	$4s^24d$ $^2D_{5/2}$	$4s4p4d\,(^3P)\,^4D_{7/2}$	-2.276	3.546E+07
10	1020.046	98034.8	1020.046	0	$4s4p4d\,(^3P)\,^2F_{7/2}$	$4s4p4f\,(^3P)\,^4G_{9/2}$	-1.152	4.462E+08
10	1035.412[d]	96579.9	1035.412	0	$4s^24d$ $^2D_{5/2}$	$4s4p4d\,(^3P)\,^4D_{3/2}$	-2.760	1.083E+07
85	1041.617[d]	96004.6	1041.616	0.001	$4s^24p$ $^2P_{1/2}$	$4s4p^2$ $^4P_{3/2}$	-4.016	5.934E+05
5	1043.095[d]	95868.5	1043.097	-0.002	$4s4p^2$ $^2P_{1/2}$	$4s^25p$ $^2P_{1/2}$	-2.869	8.277E+06
8	1043.991	95786.3	1043.993	-0.002	$4p^3$ $^2P_{3/2}$	$4s4p5p\,(^3P)\,^4P_{3/2}$	-1.883	8.030E+07
3	1061.157	94236.8	1061.162	-0.005	$4s4p4d\,(^3P)\,^4F_{3/2}$	$4s4p5p\,(^3P)\,^4P_{3/2}$	-1.706	1.166E+08
100	1069.140[d]	93533.1	1069.139	0.001	$4s^24p$ $^2P_{1/2}$	$4s4p^2$ $^4P_{1/2}$	-2.568	1.575E+07
20	1069.41	93509.5	1069.393	0.017	$4s4p4d\,(^3P)\,^4F_{7/2}$	$4s4p5p\,(^3P)\,^4D_{7/2}$	-0.779	9.622E+08
100	1072.716[d]	93221.3	1072.722	-0.006	$4s^24p$ $^2P_{3/2}$	$4s4p^2$ $^4P_{5/2}$	-2.089	4.734E+07
5	1075.092[d]	93015.3	1075.085	0.007	$4s4p^2$ $^2P_{3/2}$	$4s^25p$ $^2P_{1/2}$	-2.355	2.549E+07
5	1078.611	92711.8	1078.601	0.01	$4s4p4d\,(^3P)\,^4F_{5/2}$	$4s4p5p\,(^3P)\,^4P_{3/2}$	-1.147	4.118E+08
20	1100.564	90862.5	1100.569	-0.005	$4s4p4d\,(^3P)\,^4F_{3/2}$	$4s4p5p\,(^3P)\,^2P_{1/2}$	-1.038	5.061E+08
45	1102.673[d]	90688.7	1102.673	0	$4s4p^2$ $^2S_{1/2}$	$4p^3$ $^2D_{3/2}$	-1.198	3.461E+08
45	1108.183	90237.8	1108.183	0	$4s4p4d\,(^3P)\,^4F_{5/2}$	$4s4p5p\,(^3P)\,^4D_{5/2}$	-0.638	1.254E+09
90	1112.127[d]	89917.8	1112.127	0	$4s^24p$ $^2P_{3/2}$	$4s4p^2$ $^4P_{3/2}$	-2.795	8.647E+06
70	1127.864	88663.2	1127.874	-0.01	$4s4p4d\,(^3P)\,^4F_{7/2}$	$4s4p5p\,(^3P)\,^4D_{5/2}$	0.110	6.735E+09
10	1132.475	88302.2	1132.469	0.006	$4s4p4d\,(^3P)\,^4F_{3/2}$	$4s4p5p\,(^3P)\,^4D_{3/2}$	-0.817	7.951E+08
50	1143.558[d]	87446.4	1143.559	-0.001	$4s^24p$ $^2P_{3/2}$	$4s4p^2$ $^4P_{1/2}$	-2.932	5.961E+06
5	1149.084	87025.8	1149.078	0.006	$4s4p4d\,(^3P)\,^2P_{3/2}$	$4s4p4f\,(^3P)\,^2D_{5/2}$	-0.480	5.703E+09
5	1150.532	86916.3	1150.541	-0.009	$4s4p4d\,(^3P)\,^4D_{7/2}$	$4s25g\,(^1S)\,^2G_{9/2}$	-0.973	5.349E+08
10	1155.65	86531.4	1155.65	0	$4s4p4d\,(^3P)\,^4F_{3/2}$	$4s4p5p\,(^3P)\,^4D_{1/2}$	-0.387	2.046E+09
20	1171.069[d]	85392.1	1171.069	0	$4s4p^2$ $^2P_{1/2}$	$4p^3$ $^4S_{3/2}$	-2.674	1.030E+07
30	1211.548	82539	1211.540	0.008	$4s4p^2$ $^2P_{3/2}$	$4p^3$ $^4S_{3/2}$	-1.863	6.241E+07
5	1215.477	82272.2	1215.479	-0.002	$4s4p4d\,(^3P)\,^4D_{7/2}$	$4s4p5p\,(^3P)\,^2D_{5/2}$	-1.539	1.334E+08
45	1219.294[d]	82014.7	1219.295	-0.001	$4s4p^2$ $^2P_{1/2}$	$4p^3$ $^2D_{3/2}$	-0.910	5.510E+08
40	1229.569	81329.3	1229.553	0.016	$4s^24f$ $^2F_{5/2}$	$4s^25g\,(^1S)\,^2G_{7/2}$	0.611	1.799E+10
62	1234.235	81021.8	1234.216	0.019	$4s^24f$ $^2F_{7/2}$	$4s^25g\,(^1S)\,^2G_{7/2}$	-0.701	8.719E+08
62	1234.235	81021.8	1234.237	-0.002	$4s^24f$ $^2F_{7/2}$	$4s^25g\,(^1S)\,^2G_{9/2}$	0.843	3.054E+10
80	1244.128[d]	80377.6	1244.139	-0.011	$4s4p^2$ $^2P_{3/2}$	$4p^3$ $^2D_{5/2}$	-0.581	1.130E+09
10	1244.632	80345	1244.648	-0.016	$4s4p4d\,(^3P)\,^2D_{5/2}$	$4s^25g\,(^1S)\,^2G_{7/2}$	0.131	5.816E+09
10	1262.776	79190.6	1262.786	-0.01	$4s4p4d\,(^3P)\,^4P_{1/2}$	$4s4p5p\,(^3P)\,^2D_{3/2}$	-0.950	4.759E+08
10	1263.237[d]	79161.7	1263.231	0.006	$4s4p^2$ $^2P_{3/2}$	$4p^3$ $^2D_{3/2}$	-2.124	3.135E+07
10	1265.034	79049.3	1265.033	0.001	$4s4p4d\,(^3P)\,^4D_{5/2}$	$4s4p5p\,(^3P)\,^2D_{3/2}$	-1.012	4.097E+08
5	1265.668	79009.7	1265.655	0.013	$4s4p4d\,(^3P)\,^4P_{3/2}$	$4s4p5p\,(^3P)\,^2D_{3/2}$	-0.866	5.744E+08
15	1278.614	78209.7	1278.606	0.008	$4s4p4d\,(^3P)\,^4P_{1/2}$	$4s4p5p\,(^3P)\,^4S_{3/2}$	-0.768	6.999E+08
15	1280.902	78070	1280.910	-0.008	$4s4p4d\,(^3P)\,^4D_{5/2}$	$4s4p5p\,(^3P)\,^4S_{3/2}$	-0.834	5.974E+08
25	1281.543	78030.9	1281.547	-0.004	$4s4p4d\,(^3P)\,^4P_{3/2}$	$4s4p5p\,(^3P)\,^4S_{3/2}$	-0.622	9.737E+08
10	1286.093[d]	77754.9	1286.104	-0.011	$4s^24d$ $^2D_{5/2}$	$4p^3$ $^2P_{3/2}$	-1.898	5.092E+07

40	1313.022	76160.2	1313.027	-0.005	$4s4p4d\,(^1P)\,^2F_{7/2}$	$4s26g\,(^1S)\,^2G_{9/2}$	-0.185	2.513E+09
5	1316.103	75981.9	1316.106	-0.003	$4s4p4d\,(^1P)\,^2P_{1/2}$	$4s4p5p\,(^1P)\,^2S_{1/2}$	-0.919	4.564E+08
30	1319.332	75795.9	1319.315	0.017	$4s4p4d\,(^3P)\,^4D_{7/2}$	$4s4p5p\,(^3P)\,^4P_{5/2}$	-0.005	3.787E+09
30	1319.752	75771.8	1319.764	-0.012	$4s4p4d\,(^3P)\,^4D_{7/2}$	$4s4p5p\,(^3P)\,^4D_{7/2}$	-0.375	1.593E+09
6	1321.021	75699	1321.020	0.001	$4s4p4d\,(^3P)\,^2D_{5/2}$	$4s4p5p\,(^3P)\,^2D_{5/2}$	-0.982	4.079E+08
25	1326.898	75363.7	1326.897	0.001	$4s4p4d\,(^3P)\,^4D_{5/2}$	$4s4p5p\,(^3P)\,^4P_{5/2}$	-0.091	3.076E+09
20	1327.573	75325.4	1327.580	-0.007	$4s4p4d\,(^3P)\,^4P_{3/2}$	$4s4p5p\,(^3P)\,^4P_{5/2}$	-0.610	9.312E+08
30	1328.073	75297.1	1328.074	-0.001	$4s^25d\ ^2D_{5/2}$	$4s^27p\ ^2P_{3/2}$	-0.756	6.607E+08
30	1334.756	74920.1	1334.757	-0.001	$4s4p4d\,(^3P)\,^4D_{3/2}$	$4s4p5p\,(^3P)\,^4P_{1/2}$	-0.609	9.115E+08
8	1335.719	74866	1335.716	0.003	$4s4p4d\,(^1P)\,^2P_{3/2}$	$4s4p5p\,(^1P)\,^2S_{1/2}$	-0.668	7.937E+08
50	1338.616[d]	74704	1338.609	0.007	$4s^25p\ ^2P_{1/2}$	$4s^26s\ ^2S_{1/2}$	-0.335	1.721E+09
7	1339.678	74644.8	1339.683	-0.005	$4s4p4d\,(^3P)\,^4P_{5/2}$	$4s4p5p\,(^3P)\,^2P_{3/2}$	-0.233	2.162E+09
25	1344.637	74369.5	1344.634	0.003	$4s4p4d\,(^3P)\,^4D_{1/2}$	$4s4p5p\,(^3P)\,^4P_{1/2}$	-0.561	1.002E+09
10	1347.784	74195.9	1347.782	0.002	$4s4p4d\,(^3P)\,^2F_{5/2}$	$4s^25g\,(^1S)\,^2G_{7/2}$	-1.442	1.324E+08
25	1362.541	73392.3	1362.546	-0.005	$4s4p4d\,(^3P)\,^2D_{3/2}$	$4s4p5p\,(^3P)\,^2D_{3/2}$	-0.982	3.776E+08
100	1371.306[d]	72923.2	1371.314	-0.008	$4s^25p\ ^2P_{3/2}$	$4s^26s\ ^2S_{1/2}$	-0.050	3.160E+09
20	1377.923	72573	1377.919	0.004	$4s4p4d\,(^1P)\,^2F_{7/2}$	$4s4p5p\,(^1P)\,^2D_{5/2}$	-0.093	2.849E+09
5	1390.266	71928.7	1390.248	0.018	$4s4p4d\,(^3P)\,^2D_{5/2}$	$4s4p5p\,(^3P)\,^4S_{3/2}$	-1.473	1.162E+08
40	1409.997	70922.1	1409.990	0.007	$4s4p4d\,(^3P)\,^4D_{7/2}$	$4s4p5p\,(^3P)\,^4D_{5/2}$	-0.619	8.028E+08
35	1412.731	70784.9	1412.731	0	$4s4p4d\,(^1P)\,^2F_{5/2}$	$4s4p5p\,(^1P)\,^2D_{3/2}$	-0.290	1.734E+09
15	1415.216	70660.6	1415.220	-0.004	$4s4p4d\,(^1P)\,^2F_{5/2}$	$4s4p4f\,(^3P)\,^2G_{7/2}$	-0.417	1.275E+09
35	1474.152[d]	67835.6	1474.151	0.001	$4s^24d\ ^2D_{3/2}$	$4s^25p\ ^2P_{3/2}$	-0.928	3.619E+08
90	1487.872[d]	67210.1	1487.879	-0.007	$4s^24d\ ^2D_{5/2}$	$4s^25p\ ^2P_{3/2}$	0.013	3.100E+09
35	1497.874	66761.3	1497.872	0.002	$4s4p4d\,(^3P)\,^2F_{5/2}$	$4s4p5p\,(^3P)\,^2D_{3/2}$	-0.202	1.889E+09
20	1532.175	65266.7	1532.177	-0.002	$4s4p4d\,(^3P)\,^2D_{3/2}$	$4s4p5p\,(^3P)\,^4P_{1/2}$	-1.113	2.157E+08
10	1533.518	65209.5	1533.519	-0.001	$4s4p4d\,(^1P)\,^2D_{5/2}$	$4s4p5p\,(^1P)\,^2P_{3/2}$	-0.347	1.294E+09
30	1540.652	64907.6	1540.642	0.01	$4s4p4d\,(^3P)\,^2F_{7/2}$	$4s4p5p\,(^3P)\,^2D_{5/2}$	0.173	4.296E+09
15	1564.147	63932.6	1564.142	0.005	$4s4p4d\,(^3P)\,^2D_{3/2}$	$4s4p5p\,(^3P)\,^2P_{1/2}$	-0.834	3.990E+08
50	1615.590[d]	61896.9	1615.596	-0.006	$4s^25p\ ^2P_{1/2}$	$4s^25d\ ^2D_{3/2}$	0.364	5.905E+09
80	1656.757[d]	60358.9	1656.755	0.002	$4s^25p\ ^2P_{3/2}$	$4s^25d\ ^2D_{5/2}$	0.606	9.803E+09
90	1663.478	60115.01	1663.478	0.0002	$4s^25p\ ^2P_{3/2}$	$4s^25d\ ^2D_{3/2}$	-0.347	1.083E+09
5	1711.361	58433	1711.368	-0.007	$4s4p4d\,(^3P)\,^2F_{7/2}$	$4s4p5p\,(^3P)\,^4P_{5/2}$	-1.497	7.245E+07
5	1871.634	53429.25	1871.639	-0.005	$4s4p5s\,(^3P)\,^4P_{3/2}$	$4s4p5p\,(^3P)\,^2D_{5/2}$	-1.609	4.848E+07
8	1891.772[d]	52860.49	1891.768	0.004	$4s^25s\ ^2S_{1/2}$	$4p^3\ ^2P_{3/2}$	-1.554	5.198E+07
8	1936.699	51634.25	1936.700	-0.001	$4s4p5s\,(^3P)\,^2P_{1/2}$	$4s4p5p\,(^3P)\,^2S_{1/2}$	-0.410	6.957E+08

25	1941.006	51519.68	1941.013	-0.007	4s4p5s (^{3}P) ^{4}P$_{1/2}$	4s4p5p (^{3}P) ^{4}S$_{3/2}$	-1.324	8.412E+07
	λ_{obs} in air		λ_{Ritz} in air					
10	2047.887[e]	48815.2	2047.881	0.006	4s4p5s (^{3}P) ^{2}P$_{3/2}$	4s4p5p (^{3}P) ^{2}S$_{1/2}$	-0.076	1.327E+09
10	2308.151[e]	43311.4	2308.135	0.016	4s4p5s (^{3}P) ^{4}P$_{1/2}$	4s4p5p (^{3}P) ^{2}P$_{3/2}$	-0.040	1.126E+09
80	2362.436[e]	42316.3	2362.441	-0.004	4s^{2}5s ^{2}S$_{1/2}$	4s^{2}5p ^{2}P$_{3/2}$	0.158	1.720E+09

[B]Blended with other line,[S]Shoulder line, [w]wide line.

[a] Intensity figures are visual estimates of photographic blackening.

[b] Observed wavelength value- calculated value from the Table 5.2.

[c] Transition probabilities (gA) obtained by Cowan's code. Here g is the statistical weight of the upper level while for gf, g refers to the weight of the lower level.

[d] Lines originally classified by Tauheed and Joshi Ref.[3].

[e] Lines above 2000Å were taken from ref. [6]

Table 5.2: Observed energy levels of Br V.

Designation[a]	Energy(cm^{-1})	D_1(cm^{-1})[b]	D_2(cm^{-1})[c]	No. of connecting lines[d]
$4s^24p$ $^2P_{1/2}$	0[e]	0.3	0	16
$4s^24p$ $^2P_{3/2}$	6086.9[e]	0.2	0.4	21
$4s4p^2$ $^4P_{1/2}$	93533.2[e]	0.3	0.4	12
$4s4p^2$ $^4P_{3/2}$	96004.7[e]	0.3	0.4	23
$4s4p^2$ $^4P_{5/2}$	99307.7[e]	0.4	0.5	20
$4s4p^2$ $^2D_{3/2}$	122896.5[e]	0.3	0.4	27
$4s4p^2$ $^2D_{5/2}$	123625.9[e]	0.4	0.4	23
$4s4p^2$ $^2S_{1/2}$	149495.3[e]	0.4	0.4	19
$4s4p^2$ $^2P_{1/2}$	158169.4[e]	0.2	0.4	16
$4s4p^2$ $^2P_{3/2}$	161021.9[e]	0.2	0.4	26
$4s^24d$ $^2D_{3/2}$	187983.8[e]	0.2	0.4	19
$4s^24d$ $^2D_{5/2}$	188609.7[e]	0.3	0.4	21
$4s^25s$ $^2S_{1/2}$	213503.3[e]	0.13	0.4	12
$4p^3$ $^2D_{3/2}$	240184.0[e]	0.2	0.4	16
$4p^3$ $^2D_{5/2}$	241398.8[e]	0.4	0.4	14
$4p^3$ $^4S_{3/2}$	243561.5[e]	0.3	0.4	9
$4s^25p$ $^2P_{1/2}$	254037.8[e]	0.2	0.4	11
$4s^25p$ $^2P_{3/2}$	255819.5[e]	0.04	0.4	16
$4p^3$ $^2P_{1/2}$	265426.8[e]	0.4	0.5	6
$4p^3$ $^2P_{3/2}$	266363.9[e]	0.2	0.4	15
$4s4p4d$ (^3P) $^4F_{3/2}$	267913.7[e]	0.3	0.4	12
$4s4p4d$ (^3P) $^4F_{5/2}$	269437.3[e]	0.4	0.5	9
$4s4p4d$ (^3P) $^4F_{7/2}$	271012.7[e]	0.5	0.4	13
$4s4p4d$ (^3P) $^4P_{5/2}$	284402.9[e]	0.4	0.4	12
$4s4p4d$ (^3P) $^4D_{3/2}$	285189.6[e]	0.3	0.4	12
$4s4p4d$ (^3P) $^4D_{1/2}$	285739.9[e]	0.3	0.5	5
$4s4p4d$ (^3P) $^4D_{7/2}$	288752.6[e]	0.3	0.4	12
$4s4p4d$ (^3P) $^4P_{1/2}$	289045.0[e]	0.5	0.4	3
$4s4p4d$ (^3P) $^4D_{5/2}$	289185.7[e]	0.3	0.4	11
$4s4p4d$ (^3P) $^4P_{3/2}$	289224.5[e]	0.3	0.4	9
$4s^24f$ $^2F_{5/2}$	294339.2[e]	0.5	0.4	12
$4s^24f$ $^2F_{7/2}$	294646.5[e]	0.5	0.5	8
$4s4p4d$ (^3P) $^2D_{3/2}$	294843.0[e]	0.2	0.4	12
$4s4p4d$ (^3P) $^2D_{5/2}$	295325.6[e]	0.4	0.4	12
$4s4p4d$ (^3P) $^2F_{5/2}$	301473.6[e]	0.2	0.4	13
$4s4p4d$ (^3P) $^2F_{7/2}$	306116.7[e]	0.2	0.4	10
$4s4p5s$ (^3P) $^4P_{1/2}$	315735.7[e]	0.2	0.4	5
$4s^25d$ $^2D_{3/2}$	315934.5[e]	0.04	0.4	4
$4s^25d$ $^2D_{5/2}$	316178.4[e]	0.2	0.4	3
$4s4p5s$ (^3P) $^4P_{3/2}$	317595.6[e]	0.3	0.4	11
$4s4p4d$ (^3P) $^2P_{3/2}$	319697.1[e]	0.4	0.5	10
$4s4p4d$ (^3P) $^2P_{1/2}$	320270.6[e]	0.5	0.5	6
$4s4p5s$ (^3P) $^4P_{5/2}$	321956.0[e]	2	2	2

4s4p5s (^{3}P) $^2P_{1/2}$	327343.1^e	0.2	0.5	4
4s^{2}6s $^2S_{1/2}$	328742.2^e	0.3	0.4	2
4s4p5s (^{3}P) $^2P_{3/2}$	330162.0^e	0.3	0.5	9
4s4p4d (^{1}P) $^2F_{7/2}$	335148.3^e	0.3	0.5	5
4s4p4d (^{1}P) $^2F_{5/2}$	335823.8^e	0.2	0.5	8
4s4p4d (^{1}P) $^2D_{3/2}$	338251.0^e	0.9	0.7	5
4s4p4d (^{1}P) $^2P_{1/2}$	338628.5^e	0.3	0.6	5
4s4p4d (^{1}P) $^2D_{5/2}$	339668.0^e	0.2	0.7	3
4s4p4d (^{1}P) $^2P_{3/2}$	339744.0^e	0.3	0.6	5
4s^{2}6p $^2P_{1/2}$	346327.5^e	0.8	0.7	6
4s^{2}6p $^2P_{3/2}$	347363.3^e	1.0	0.7	6
4s4p5p (^{3}P) $^4D_{1/2}$	354445.1	0.4	0.6	3
4s4p5p (^{3}P) $^4D_{3/2}$	356216.3	0.5	0.5	5
4s4p5p (^{3}P) $^2P_{1/2}$	358775.8	0.2	0.4	3
4s4p5p (^{3}P) $^2P_{3/2}$	359047.4	0.3	0.4	3
4s4p5p (^{3}P) $^4D_{5/2}$	359675.1	0.3	0.4	3
4s4p5p (^{3}P) $^4P_{1/2}$	360109.6	0.2	0.4	5
4s4p5p (^{3}P) $^4P_{3/2}$	362150.0	0.4	0.4	6
4s4p5p (^{3}P) $^4D_{7/2}$	364523.7	0.7	0.5	2
4s4p5p (^{3}P) $^4P_{5/2}$	364549.5	0.2	0.4	4
4s4p5s (^{1}P) $^2P_{1/2}$	365300.3^e	1.1	0.9	5
4s4p5s (^{1}P) $^2P_{3/2}$	365429.3^e	0.8	0.8	6
4s4p5p (^{3}P) $^4S_{3/2}$	367255.2	0.2	0.4	7
4s4p5p (^{3}P) $^2D_{3/2}$	368235.0	0.2	0.4	8
4s4p5p (^{3}P) $^2D_{5/2}$	371024.7	0.2	0.4	6
4s^{2}5g (^{1}S) $^2G_{9/2}$	375668.2	0.5	0.5	3
4s^{2}5g (^{1}S) $^2G_{7/2}$	375669.6	0.5	0.4	4
4s4p5p (^{3}P) $^2S_{1/2}$	378977.3	0.13	0.5	5
4s^{2}7s $^2S_{1/2}$	381546.6	0.7	0.7	4
4s^{2}7p $^2P_{1/2}$	390780.0	2	2	2
4s^{2}7p $^2P_{3/2}$	391475.4	0.3	0.5	3
4s4p4f (^{3}P) $^4D_{5/2}$	401087.6	1.3	0.7	3
4s4p4f (^{3}P) $^4D_{7/2}$	402576.4	1.1	0.6	3
4s4p4f (^{3}P) $^4G_{9/2}$	404151.5	0.5	0.6	2
4s4p5p (^{1}P) $^2P_{1/2}$	404383.3	0.6	0.7	3
4s4p5p (^{1}P) $^2P_{3/2}$	404877.5	0.2	0.7	4
4s4p4f (^{3}P) $^2G_{7/2}$	406484.2	0.2	0.5	5
4s4p5p (^{1}P) $^2D_{3/2}$	406608.7	0.3	0.5	4
4s4p4f (^{3}P) $^2D_{5/2}$	406723.4	0.4	0.5	4
4s4p5p (^{1}P) $^2D_{5/2}$	407721.5	0.4	0.5	4
4s4p4f (^{3}P) $^2D_{3/2}$	409173.8	0.4	0.6	3
4s^{2}6g (^{1}S) $^2G_{7/2}$	410559.0	0.4	0.5	5
4s^{2}6g (^{1}S) $^2G_{9/2}$	411308.2	0.3	0.5	4
4s4p5p (^{1}P) $^2S_{1/2}$	414610.2	0.2	0.6	4
4p^{2}4d (^{3}P) $^2P_{3/2}$	415255.9	2	0.7	3
4p^{2}4d (^{3}P) $^4F_{3/2}$	417457.7	0.7	0.6	4

$4p^24d$ (^3P) $^4F_{5/2}$	418287.7	1.0	0.7	3
$4p^24d$ (^3P) $^4F_{7/2}$	418771.9	1.0	0.6	4
$4p^24d$ (^1D) $^2F_{5/2}$	419177.7	0.8	0.5	5
$4p^24d$ (^1D) $^2F_{7/2}$	420895.8	1.0	0.6	4
$4p^24d$ (^3P) $^4F_{9/2}$	420945.9	0.6	0.6	3
$4p^24d$ (^3P) $^4D_{5/2}$	423089.9	0.8	0.5	7
$4p^24d$ (^3P) $^4D_{7/2}$	425461.6	1.2	0.6	5
$4p^24d$ (^1D) $^2G_{7/2}$	427071.2	1.5	0.7	2
$4p^24d$ (^3P) $^4P_{5/2}$	429117.1	0.6	0.6	5
$4p^24d$ (^1D) $^2D_{5/2}$	441014.4	2	0.8	4

[a] Represent designations of the levels
[b] Uncertainty D_1 is close to the minimum estimated dispersion relative to any other term
[c] Uncertainty of the level value relative to the ground level and both uncertainties were determine by the LOPT code[9].
[d] No. of observed transitions corresponding to each level.
[e] Levels established by Tauheed and Joshi [3].

Table 5.3: Observed and LSF energy levels of Br V in cm^{-1}.

J	E(obs)	E(LSF)	Diff.[a]	LS-composition.
Odd configurations				
1/2	0.0	-4.0	4.0	97%4s^{2}4p ^{2}P
	254037.8	254037.0	0.8	95%4s^{2}5p ^{2}P
	265426.8	265545.0	-118.2	78%4p^3 ^{2}P + 14%4s4p4d(^{3}P)^{2}P +4%4s4p4d(^{1}P)^{2}P
	285739.9	285922.0	-182.1	84%4s4p4d(^{3}P)^{4}D+15%4s4p4d(^{3}P)^{4}P
	289045.0	288906.0	139.0	84%4s4p4d(^{3}P)^{4}P +15%4s4p4d(^{3}P)^{4}D
	315735.7	315801.0	-65.3	97%4s4p5s(^{3}P)^{4}P
	320270.6	320240.0	30.6	57%4s4p4d(^{3}P)^{2}P +28%4s4p5s(^{3}P)^{2}P +8%4p^3 ^{2}P
	327343.1	327241.0	102.1	67%4s4p5s(^{3}P)^{2}P +25%4s4p4d(^{3}P)^{2}P +4%4p^3 ^{2}P
	338628.5	338859.0	-230.5	87%4s4p4d(^{1}P)^{2}P +5%4p^3 ^{2}P
	346327.5	346276.0	51.5	89%4s^{2}6p ^{2}P+ 7%4s4p5s(^{1}P)^{2}P
	365300.3	365272.0	28.3	90%4s4p5s(^{1}P)^{2}P +6%4s^{2}6p ^{2}P
	390780.0	390930.0	-150.0	99%4s^{2}7p ^{2}P
3/2	6086.9	6087.0	-0.1	97%4s^{2}4p ^{2}P
	240184.0	240116.0	68.0	65%4p^3 ^{2}D +26%4s4p4d(^{3}P)^{2}D
	243561.5	243603.0	-41.5	93%4p^3 ^{4}S
	255819.5	255820.0	-0.5	94%4s^{2}5p ^{2}P
	266363.9	266307.0	56.9	71%4p^3 ^{2}P +15%4s4p4d(^{3}P)^{2}P +4%4s4p4d(^{1}P)^{2}P
	267913.7	267953.0	-39.3	98%4s4p4d(^{3}P)^{4}F
	285189.6	285270.0	-80.4	55%4s4p4d(^{3}P)^{4}D + 43%4s4p4d(^{3}P)^{4}P
	289224.5	289147.0	77.5	56%4s4p4d(^{3}P)^{4}P + 44%4s4p4d(^{3}P)^{4}D
	294843.0	295034.0	-191.0	56%4s4p4d(^{3}P)^{2}D + 22%4s4p4d(^{1}P)^{2}D +18%4p^3 ^{2}D
	317595.6	317593.0	2.6	87%4s4p5s(^{3}P)^{4}P + 6%4s4p4d(^{3}P)^{2}P +5%4s4p5s(^{3}P)^{2}P
	319697.1	319638.0	59.1	67%4s4p4d(^{3}P)^{2}P +12%4p^3 ^{2}P +10%4s4p5s(^{3}P)^{4}P +6%4s4p5s(^{3}P)^{2}P
	330162.0	330269.0	-107.0	83%4s4p5s(^{3}P)^{2}P + 7%4s4p4d(^{3}P)^{2}P
	338251.0	338074.0	177.0	54%4s4p4d(^{1}P)^{2}D + 23%4s4p4d(^{1}P)^{2}P +8%4s4p4d(^{3}P)^{2}D + 7%4p^3 ^{2}D
	339744.0	339809.0	-65.0	65%4s4p4d(^{1}P)^{2}P +16%4s4p4d(^{1}P)^{2}D +4%4s4p4d(^{3}P)^{2}D +4%4p^3 ^{2}P
	347363.3	347408.0	-44.7	88%4s^{2}6p ^{2}P +5%4s4p5s(^{1}P)^{2}P +4%4s4p5s(^{3}P)^{2}P
	365429.3	365457.0	-27.7	90%4s4p5s(^{1}P)^{2}P +6%4s^{2}6p ^{2}P
	391475.4	391326.0	149.4	99%4s^{2}7p ^{2}P
5/2	241398.8	241343.0	55.8	70%4p^3 ^{2}D + 28%4s4p4d(^{3}P)^{2}D
	269437.3	269184.0	253.3	98%4s4p4d(^{3}P)^{4}F
	284402.9	284353.0	49.9	69%4s4p4d(^{3}P)^{4}P + 27%4s4p4d (^{3}P)^{4}D
	289185.7	289196.0	-10.3	72%4s4p4d(^{3}P)^{4}D + 26%4s4p4d (^{3}P)^{4}P
	294339.2	294445.0	-105.8	70%4s^{2}4f ^{2}F +12%4s4p4d(^{1}P)^{2}F +9%4s4p4d(^{3}P)^{2}D
	295325.6	295302.0	23.6	44%4s4p4d(^{3}P)^{2}D + 18%4s4p4d(^{1}P)^{2}D +16%4s^{2}4f^{2}F + 14%4p^3 ^{2}D
	301473.6	301529.0	-55.4	79%4s4p4d(^{3}P)^{2}F +16%4s4p4d(^{1}P)^{2}F
	321956.0	321891.0	65.0	99%4s4p5s(^{3}P)^{4}P
	335823.8	335956.0	-132.2	69%4s4p4d(^{1}P)^{2}F +15%4s4p4d(^{3}P)^{2}F +11%4s^{2}4f^{2}F
	339668.0	339390.0	278.0	71%4s4p4d(^{1}P)^{2}D +13%4s4p4d(^{3}P)^{2}D +10%4p^3 ^{2}D
7/2	271012.7	271033.0	-20.3	98%4s4p4d(^{3}P)^{4}F
	288752.6	288843.0	-90.4	97%4s4p4d(^{3}P)^{4}D
	294646.5	294563.0	83.5	85%4s^{2}4f ^{2}F + 10%4s4p4d(^{1}P)^{2}F
	306116.7	306234.0	-117.3	83%4s4p4d(^{3}P)^{2}F +16%4s4p4d(^{1}P)^{2}F
	335148.3	335028.0	120.3	71%4s4p4d(^{1}P)^{2}F +14%4s4p4d(^{3}P)^{2}F +12%4s^{2}4f ^{2}F

Even configurations

1/2	93533.2	93522.0	11.2	99%4s4p^2(^{3}P)^{4}P
	149495.3	149461.0	34.3	81%4s4p^2(^{1}S)^{2}S + 17%4s4p^2(^{3}P)^{2}P
	158169.4	158180.0	-10.6	80%4s4p^2(^{3}P)^{2}P + 18%4s4p^2(^{1}S)^{2}S
	213503.3	213503.0	0.3	97%4s^{2}5s ^{2}S
	328742.2	328742.0	0.2	100%4s^{2}6s ^{2}S
	354445.1	354632.0	-186.9	66%4s4p5p(^{3}P)^{4}D + 31%4s4p5p(^{3}P)^{2}P
	358775.8	358676.0	99.8	54%4s4p5p(^{3}P)^{2}P + 23%4s4p5p(^{3}P)^{4}D +20%4s4p5p(^{3}P)^{4}P
	360109.6	359968.0	141.6	76%4s4p5p(^{3}P)^{4}P + 10%4s4p5p(^{3}P)^{4}D +10%4s4p5p(^{3}P)^{2}P
	378977.3	378804.0	173.3	88%4s4p5p(^{3}P)^{2}S + 6%4s^{2}7s ^{2}S
	381546.6	381559.0	-12.4	93%4s^{2}7s ^{2}S + 6% 4s4p5p(^{3}P)^{2}S
	-	403965.0	-	68%4s4p4f(^{3}P)^{4}D + 30% 4p^{2}4d(^{3}P)^{4}D
	404383.3	404268.0	115.3	94%4s4p5p(^{1}P)^{2}P
	-	411678.0	-	77%4s^{2}8s ^{2}S + 21%4s4p5p(^{1}P)^{2}S
	414610.2	414645.0	-34.8	70%4s4p5p(^{1}P)^{2}S + 23%4s^{2}8s ^{2}S
3/2	96004.7	96011.0	-6.3	100%4s4p^2(^{3}P)^{4}P
	122896.5	123011.0	-114.5	89%4s4p^2(^{1}D)^{2}D +9%4s^{2}4d ^{2}D
	161021.9	161006.0	15.9	97%4s4p^2(^{3}P)^{2}P
	187983.8	187972.0	11.8	88%4s^{2}4d ^{2}D + 9%4s4p^2(^{1}D)^{2}D
	315934.5	315933.0	1.5	99%4s^{2}5d ^{2}D
	356216.3	356606.0	-389.7	75%4s4p5p(^{3}P)^{4}D + 21%4s4p5p(^{3}P)^{2}P
	359047.4	358636.0	411.4	46%4s4p5p(^{3}P)^{2}P + 29%4s4p5p(^{3}P)^{4}P +10%4s4p5p(^{3}P)^{4}D +9%4s4p5p(^{3}P)^{4}S
	362150.0	362258.0	-108.0	59%4s4p5p(^{3}P)^{4}P + 21%4s4p5p(^{3}P)^{2}P +13%4s4p5p(^{3}P)^{4}D
	367255.2	367288.0	-32.8	47%4s4p5p(^{3}P)^{4}S + 44%4s4p5p(^{3}P)^{2}D +5%4s4p5p(^{3}P)^{4}P
	368235.0	368494.0	-259.0	43%4s4p5p(^{3}P)^{2}D + 40%4s4p5p(^{3}P)^{4}S +9%4s4p5p(^{3}P)^{2}P + 4%4s4p5p(^{3}P)^{4}P
	-	374968.0	-	94%4s^{2}6d ^{2}D
	-	393231.0	-	66%4s4p4f(^{3}P)^{4}F + 31%4p^{2}4d(^{3}P)^{4}F
	-	403677.0	-	68%4s4p4f(^{3}P)^{4}D + 27%4p^{2}4d(^{3}P)^{4}D
	404877.5	405074.0	-196.5	76%4s4p5p(^{1}P)^{2}P + 18%4s4p5p(^{1}P)^{2}D
	406608.7	406684.0	-75.3	73%4s4p5p(^{1}P)^{2}D + 18%4s4p5p(^{1}P)^{2}P
	409173.8	409481.0	-307.2	87%4s4p4f(^{3}P)^{2}D + 10%4p^{2}4d(^{3}P)^{2}D
	415255.9	415833.0	-577.1	66%4p^{2}4d(^{3}P)^{2}P + 12%4p^{2}4d(^{3}P)^{4}F +12%4p^{2}4d(^{1}D)^{2}P +6%4s4p4f(^{3}P)^{4}F
	417457.7	417290.0	167.7	53%4p^{2}4d(^{3}P)^{4}F + 26%4s4p4f(^{3}P)^{4}F +12%4p^{2}4d(^{3}P)^{2}P
5/2	99307.7	99287.0	20.7	98%4s4p^2(^{3}P)^{4}P
	123625.9	123583.0	42.9	89%4s4p^2(^{1}D)^{2}D +9%4s^{2}4d ^{2}D
	188609.7	188614.0	-4.3	89%4s^{2}4d ^{2}D +9%4s4p^2(^{1}D)^{2}D
	316178.4	316180.0	-1.6	99%4s^{2}5d ^{2}D
	359675.1	359547.0	128.1	86%4s4p5p(^{3}P)^{4}D +12%4s4p5p(^{3}P)^{4}P
	364549.5	364691.0	-141.5	84%4s4p5p(^{3}P)^{4}P +13%4s4p5p(^{3}P)^{4}D
	371024.7	371400.0	-375.3	76%4s4p5p(^{3}P)^{2}D +20%4s^{2}6d ^{2}D
	-	375773.0	-	78%4s^{2}6d ^{2}D +20%4s4p5p(^{3}P)^{2}D
	-	392365.0	-	74%4s4p4f(^{3}P)^{2}F + 18%4p^{2}4d(^{3}P)^{2}F
	-	393585.0	-	63%4s4p4f(^{3}P)^{4}F + 26%4p^{2}4d(^{3}P)^{4}F
	401087.6	400945.0	142.6	68%4s4p4f(^{3}P)^{4}D + 22%4p^{2}4d(^{3}P)^{4}D
	-	403183.0	-	94%4s4p4f(^{3}P)^{4}G
	406723.4	407052.0	-328.6	59%4s4p4f(^{3}P)^{2}D + 29%4s4p5p(^{1}P)^{2}D +5%4p^{2}4d(^{3}P)^{2}D
	407721.5	407277.0	444.5	65%4s4p5p(^{1}P)^{2}D +24%4s4p4f(^{3}P)^{2}D
	418287.7[b]	416926.0	-	63%4p^{2}4d(^{3}P)^{4}F +28%4s4p4f(^{3}P)^{4}F +6%4p^{2}4d(^{3}P)^{4}D
	419177.7	419653.0	-475.3	58%4p^{2}4d (^{1}D)^{2}F + 18%4p^{2}4d(^{3}P)^{2}F +11%4s4p4f(3P)2F +5%4p^{2}4d(^{3}P)^{4}D
	423089.9	423554.0	-464.1	57%4p^{2}4d(^{3}P)^{4}D + 20%4s4p4f (^{3}P)^{4}D +7%4p^{2}4d(^{3}P)^{4}P +5%4p^{2}4d(^{1}D)^{2}F
	429117.1	429048.0	69.1	89%4p^{2}4d(^{3}P)^{4}P +6%4p^{2}4d(^{3}P)^{4}D

	-	439757.0	-	$65\%4s4p4f(^1P)^2F + 15\%4p^24d(^3P)^2F + 12\%4p^24d(^1D)^2D$
	441014.4	*441074.0*	*-59.6*	$69\%4p^24d(^1D)^2D + 12\%4s4p4f(^1P)^2F + 5\%4p^24d(^3P)^2D$
7/2	364523.7	364083.0	440.7	$99\%4s4p5p\,(^3P)^4D$
	375669.6	375669.0	0.6	$98\%4s^25g\,^2G$
	-	393402.0	-	$56\%4s4p4f(^3P)^2F + 17\%4s4p4f(^3P)^4F + 12\%4p^24d(^3P)^2F + 6\%4p^24d(^3P)^4F$
	-	394504.0	-	$49\%4s4p4f(^3P)^4F + 21\%4s4p4f(^3P)^2F + 18\%4p^24d(^3P)^4F + 5\%4s4p4f(^3P)^4G$
	-	401846.0	-	$58\%4s4p4f(^3P)^4G + 28\%4s4p4f(^3P)^4D + 7\%4p^24d(^3P)^4D + 4\%4s4p4f(^3P)^2G$
	402576.4	402686.0	-109.6	$44\%4s4p4f(^3P)^4D + 33\%4s4p4f(^3P)^4G + 11\%4p^24d(^3P)^4D + 6\%4s4p4f(^3P)^4F$
	406484.2	406586.0	-101.8	$74\%4s4p4f(^3P)^2G + 10\%4p^24d(^1D)^2G + 5\%4s4p4f(^1P)^2G$
	410559.0	410824.0	-265.0	$93\%4s^26g\,^2G + 5\%4s4p4f(^3P)^2G$
	418771.9	418359.0	412.9	$64\%4p^24d(^3P)^4F + 26\%4s4p4f(^3P)^4F + 7\%4p^24d(^3P)^4D$
	420895.8	420776.0	119.8	$48\%4p^24d(^1D)^2F + 19\%4p^24d(^3P)^4D + 13\%4p^24d(^3P)^2F + 8\%4s4p4f(^3P)^4D$
	425461.6	425420.0	41.6	$50\%4p^24d(^3P)^4D + 13\%4p^24d(^1D)^2F + 11\%4s4p4f(^3P)^4D + 6\%4p^24d(^1D)^2G$
	427071.2	426546.0	525.2	$41\%4p^24d(^1D)^2G + 19\%4s4p4f(^1P)^2G + 12\%4s4p4f(^3P)^2G + 11\%4s^27g\,^2G$
	-	433026.0	-	$87\%4s^27g\,^2G + 11\%4p^24d(^1D)^2G$
9/2	375668.2	375671.0	-2.8	$98\%4s^25g\,^2G$
	-	395577.0	-	$71\%4s4p4f(^3P)^4F + 23\%4p^24d(^3P)^4F + 4\%4s4p4f(^3P)^4G$
	404151.5	403862.0	289.5	$93\%4s4p4f(^3P)^4G$
	-	409796.0	-	$56\%4s4p4f(^3P)^2G + 24\%4s^26g\,^2G + 13\%4p^24d(^1D)^2G + 6\%4s4p4f(^1P)^2G$
	411308.2	410981.0	327.2	$71\%4s^26g\,^2G + 26\%4s4p4f(^3P)^2G$
	420945.9	420515.0	430.9	$69\%4p^24d(^3P)^4F + 26\%4s4p4f(^3P)^4F$
	-	426303.0	-	$44\%4p^24d(^1D)^2G + 23\%4s4p4f(^1P)^2G + 12\%4s^27g\,^2G + 11\%4s4p4f(^3P)^2G$
	-	433119.0	-	$86\%4s^27g\,^2G + 11\%4p^24d(^1D)^2G$

[a]Difference between experimental and LSF energy levels.
[b]This level was not fitted due to interaction, so not included in LSF calculation.

'able 5.4: LSF and HFR parameters of odd configurations of Br V in cm^{-1}.

:onfiguration	parameter	LSF	accuracy	HF	LSF/HF
$4s^24p$	$E_{av}(4s^2 4p)$	12857.1	169.0	11437.3	
	$\xi(4p)$	4161.1	162.0	3784.7	1.099
$4s^25p$	$E_{av}(4s^25p)$	264072.3	177.0	264316.0	0.993
	$\xi(5p)$	1244.4	167.0	1125.8	1.105
$4s^26p$	$E_{av}(4s^26p)$	347641.5	136.0	354959.0	0.975
	$\xi(6p)$	515.8	(fixed)	515.9	1.000
$4s^27p$	$E_{av}(4s^27p)$	390992.3	120.0	399523.3	0.974
	$\xi(7p)$	281.2	(fixed)	281.3	1.000
$4s^28p$	$E_{av}(4s^28p)$	424969.9	(fixed)	424971.4	0.997
	$\xi(8p)$	170.5	(fixed)	170.5	1.000
$4s^24f$	$E_{av}(4s^24f)$	306157.9	384.0	308803.5	0.986
	$\xi(4f)$	2.7	(fixed)	2.7	1.000
$4p^3$	$E_{av}(4p^3)$	266527.5	205.0	265545.0	0.998
	$F^2(4p,4p)$	55050.1	606.0	62427.4	0.882
	$\xi(4p)$	4234.8	344.0	3772.3	1.123
4s4p4d	$E_{av}(4s4p4d)$	300475.9	52.0	298137.0	1.003
	$\xi(4p)$	4271.3	100.0	3913.9	1.091
	$\xi(4d)$	225.9	(fixed)	226.0	1.000
	$F^2(4p,4d)$	38451.2	436.0	49539.1	0.776
	$G^1(4s,4p)$	68585.0	229.0	84396.0	0.813
	$G^2(4s,4d)$	34830.2	460.0	40838.9	0.853
	$G^1(4p,4d)$	47978.4	322.0	59586.7	0.805
	$G^2(4p,4d)$	0.0	(fixed)	0.0	
	$G^3(4p,4d)$	24899.1	772.0	36979.5	0.673
4s4p5d	$E_{av}(4s4p5d)$	434584.4	(fixed)	434584.4	0.997
	$\xi(4p)$	4113.5	(fixed)	4113.5	1.000
	$\xi(5d)$	89.7	(fixed)	89.7	1.000
	$F^2(4p,5d)$	13611.3	(fixed)	16013.4	0.850
	$G^1(4s,4p)$	64509.8	(fixed)	86013.1	0.750
	$G^2(4s,5d)$	6947.5	(fixed)	9263.4	0.750
	$G^1(4p,5d)$	7755.6	(fixed)	10340.9	0.750
	$G^3(4p,5d)$	5554.0	(fixed)	7405.4	0.750
4s4p5s	$E_{av}(4s4p5s)$	333867.8	76.0	333154.2	0.998
	$\xi(4p)$	4436.5	141.0	4060.8	1.093
	$G^1(4s,4p)$	62973.0	248.0	85476.7	0.737
	$G^0(4s,5s)$	4298.3	138.0	5234.4	0.821
	$G^1(4p,5s)$	5256.0	(fixed)	7522.9	0.699
4s4p6s	$E_{av}(4s4p6s)$	447099.3	(fixed)	447105.4	0.997
	$\xi(4p)$	4132.6	(fixed)	4132.6	1.000
	$G^1(4s,4p)$	64586.3	(fixed)	86115.2	0.750
	$G^0(4s,6s)$	1284.3	(fixed)	1712.5	0.750
	$G^1(4p,6s)$	1799.4	(fixed)	2399.3	0.750
$4p4d^2$	$E^0(4p4d^2)$	603179.0	(fixed)	603184.8	0.998
$4p5s^2$	$E^0(4p\ 5s^2)$	696297.7	(fixed)	696307.9	0.998
	$\xi(4p)$	4343.9	(fixed)	4344.0	1.000
$4p^25p$	$E^0(4p^2\ 5p)$	508905.0	(fixed)	508909.5	0.997
$4p^24f$	$E^0(4p^24f)$	553313.7	(fixed)	553320.2	0.997

R^k parameters					
$4s^24p$-$4p^3$	$R^1(4s,4s;4p,4p)$	71976.5	508.0	83409.8	0.863
$4s^24p$-$4s4p4d$	$R^1(4s,4p;4p,4d)$	59548.8	421.0	69007.9	0.863
	$R^2(4s,4p;4d,4p)$	43826.8	310.0	50788.5	0.863
$4s^24p$-$4s4p5s$	$R^0(4s,4s;4s,5s)$	3739.4	26.0	4333.4	0.863
	$R^1(4s,4p;4p,5s)$	1655.4	12.0	1918.4	0.863
	$R^0(4s,4p;5s,4p)$	369.8	3.0	428.6	0.863
$4s^25p$-$4s4p4d$	$R^1(4s,5p;4p,4d)$	-1986.5	-14.0	-2302.6	0.863
	$R^2(4s,5p;4d,4p)$	6696.2	47.0	7759.9	0.863
$4s^25p$-$4s4p5s$	$R^1(4s,5p;4p,5s)$	29994.7	212.0	34759.3	0.863
	$R^0(4s,5p;5s,4p)$	4366.6	31.0	5060.2	0.863
$4s^25p$-$4p^25p$	$R^1(4s,4s;4p,4p)$	74133.7	524.0	85909.6	0.863
$4s^26p$-$4s4p4d$	$R^1(4s,6p;4p,4d)$	-1460.8	-10.0	-1692.9	0.863
	$R^2(4s,6p;4d,4p)$	2712.2	19.0	3143.0	0.863
$4s^26p$-$4s4p5s$	$R^1(4s,6p;4p,5s)$	13586.9	96.0	15745.1	0.863
	$R^0(4s,6p;5s,4p)$	2598.9	18.0	3011.8	0.863
$4s^24f$-$4s4p5d$	$R^2(4s,4f;5d,4p)$	31920.5	761.0	45538.7	0.701
	$R^1(4s,4s;4p,4p)$	18665.3	445.0	26628.4	0.701
$4p^3$-$4s4p5s$	$R^1(4p,4p;4s,5s)$	73887.5	522.0	85624.2	0.863
$4p^3$-$4s4p6s$	$R^1(4p,4p;4s,6s)$	59157.4	418.0	68554.4	0.863
$4p^3$-$4p4d^2$	$R^3(4p,4p;4d,4d)$	1786.6	13.0	2070.4	0.863
$4p^3$-$4p^25p$	$R^0(4p,4p;4p,5p)$	54003.1	381.0	62581.3	0.863
	$R^2(4p,4p;4p,5p)$	33505.6	237.0	38827.9	0.863
$4p^3$-$4p^24f$	$R^2(4p,4p;4p,4f)$	7694.9	54.0	8917.3	0.863
$4s4p4d$-$4p^25p$	$R^1(4s,4d;4p,5p)$	61029.3	431.0	70723.7	0.863
	$R^1(4s,4d;5p,4p)$	44991.2	318.0	52137.9	0.863
	$R^1(4s,4d;4p,4f)$	36942.8	261.0	42811.0	0.863
	Standard deviation σ	166.0			

Table 5.5: LSF and HFR parameters of even configurations of Br V in cm^{-1}.

configuration	parameter	LSF	accuracy	HF	LSF/HF
$4s4p^2$	$E_{av}(4s4p^2)$	127164.4	259.0	126321.3	0.995
	$F^2(4p,4p)$	49749.0	855.0	62446.2	0.797
	$\xi(4p)$	4260.1	366.0	3776.3	1.128
	$G^1(4s,4p)$	68989.2	463.0	83427.9	0.827
$4s^24d$	$E_{av}(4s^24d)$	189705.9	310.0	191132.2	0.984
	$\xi(4d)$	296.6	229.0	218.1	1.360
$4s^25d$	$E_{av}(4s^25d)$	316594.2	264.0	324550.8	0.970
	$\xi(5d)$	106.3	206.0	88.7	1.198
$4s^26d$	$E_{av}(4s^26d)$	375451.7	(fixed)	383710.2	0.974
	$\xi(6d)$	45.2	(fixed)	45.2	1.000
$4s^25s$	$E_{av}(4s^25s)$	220917.5	504.0	222264.6	0.987
$4s^26s$	$E_{av}(4s^26s)$	328935.5	361.0	336106.1	0.974
$4s^27s$	$E_{av}(4s^27s)$	381496.8	387.0	389405.6	0.975
$4s^28s$	$E_{av}(4s^28s)$	412348.8	(fixed)	418902.9	0.980
$4s^29s$	$E_{av}(4s^29s)$	420583.2	(fixed)	436987.7	0.958
$4s^25g$	$E_{av}(4s^25g)$	376630.2	263.0	378124.6	0.992
	$\xi(5g)$	0.7	(fixed)	0.7	1.000
$4s^26g$	$E_{av}(4s^2 6g)$	411741.0	316.0	412187.0	0.995
	$\xi(6g)$	0.4	(fixed)	0.4	1.00
$4s^27g$	$E_{av}(4s^27g)$	432671.8	(fixed)	432675.0	0.997
	$\xi(7g)$	0.2	(fixed)	0.2	1.000
$4s^28g$	$E_{av}(4s^28g)$	445948.6	(fixed)	445953.2	0.997
	$\xi(8g)$	0.2	(fixed)	0.2	1.00
$4p^24d$	$E_{av}(4p^24d)$	432080.1	491.0	429635.3	1.002
	$F^2(4p,4p)$	54868.6	3501.0	63189.2	0.868
	$\xi(4p)$	3903.7	(fixed)	3903.8	1.000
	$\xi(4d)$	234.8	(fixed)	234.8	1.000
	$F^2(4p,4d)$	42400.4	2528.0	50170.9	0.845
	$G^1(4p,4d)$	41659.1	1678.0	60702.6	0.686

	$G^3(4p,4d)$	25853.8	1042.0	37672.3	0.686
$4p^25s$	$E_{av}(4p^25s)$	469195.7	(fixed)	469195.6	0.997
	F2(4p,4p)	54470.8	(fixed)	64083.4	0.850
	$\xi(4p)$	4053.3	(fixed)	4053.4	1.000
	$G^1(4p,5s)$	5762.9	(fixed)	7684.0	0.750
4s4p5p	$E_{av}(4s4p5p)$	375154.3	104.0	374152.1	0.999
	$\xi(4p)$	5160.9	236.0	4118.0	1.253
	$\xi(5p)$	1181.8	(fixed)	1125.5	1.050
	$F^2(4p,5p)$	20633.4	573.0	21422.9	0.963
	$G^1(4s,4p)$	63549.0	347.0	85977.6	0.739
	$G^1(4s,5p)$	5946.2	32.0	8044.8	0.739
	$G^0(4p,5p)$	3945.8	22.0	5338.5	0.739
	$G^2(4p,5p)$	4987.0	27.0	6747.1	0.739
4s4p4f	$E_{av}(4s4p4f)$	416066.7	238.0	418650.5	0.990
	$\xi(4p)$	4470.2	535.0	4086.8	1.094
	$\xi(4f)$	2.8	(fixed)	2.9	0.966
	$F^2(4p,4f)$	23806.5	(fixed)	28007.7	0.850
	$G^1(4s,4p)$	63490.9	1073.0	85690.5	0.741
	$G^3(4s,4f)$	9056.7	153.0	12223.3	0.741
	$G^2(4p,4f)$	14322.4	242.0	19330.3	0.741
	$G^4(4p,4f)$	9550.5	161.0	12889.9	0.741
R^k parameters:					
$4s4p^2$ -$4s^24d$	$R^1(4p,4p;4s,4d)$	54040.8	1244.0	67946.4	0.795
$4s4p^2$ -$4s^25d$	$R^1(4p,4p;4s,5d)$	22431.1	516.0	28203.4	0.795
$4s4p^2$ -$4p^24d$	$R^1(4s,4p;4p,4d)$	55418.0	1275.0	69679.1	0.795
	$R^2(4s,4p;4d,4p)$	40773.9	938.0	51266.4	0.795
$4s4p^2$-4s4p5p	$R^0(4s,4p;4s,5p)$	2676.4	62.0	3365.1	0.795
	$R^1(4s,4p;5p,4s)$	15708.3	362.0	19750.6	0.795
	$R^0(4p,4p;4p,5p)$	1792.2	41.0	2253.4	0.795
	$R^2(4p,4p;4p,5p)$	8277.0	190.0	10407.0	0.795
$4s4p^2$-4s4p4f	$R^2(4p,4p;4p,4f)$	26289.2	605.0	33054.4	0.795
$4s^24d$-$4p^24d$	$R^1(4s,4s;4p,4p)$	67075.0	1544.0	84335.7	0.795
$4s^24d$-4s4p5p	$R^1(4s,4d;4p,5p)$	-2801.3	-64.0	-3522.1	0.795
	$R^1(4s,4d;5p,4p)$	10278.7	237.0	12923.8	0.795
$4s^24d$-4s4p4f	$R^1(4s,4d;4p,4f)$	36941.0	850.0	46447.2	0.795
	$R^3(4s,4d;4f,4p)$	16869.8	388.0	21211.0	0.795
$4s^25d$-4s4p5p	$R^1(4s,5d;4p,5p)$	18397.2	423.0	23131.5	0.795
	$R^1(4s,5d;5p,4p)$	6128.5	141.0	7730.6	0.793
$4s^25s$-$4p^25s$	$R^1(4s,4s;4p,4p)$	67954.7	1564.0	85441.7	0.795
$4s^25s$ -4s4p5p	$R^1(4s,5s;4p,5p)$	27636.4	636.0	34748.3	0.795
	$R^1(4s,5s;5p,4p)$	4235.1	97.0	5325.0	0.795
$4s^26s$-4s4p5p	$R^1(4s,6s;4p,5p)$	5592.3	129.0	7031.3	0.795
	$R^1(4s,6s;5p,4p)$	2112.6	49.0	2656.2	0.795

$4s^25g$-$4s4p4f$	$R^1(4s,5g;4p,4f)$	-15236.4	-351.0	-19157.2	0.795
	$R^3(4s,5g;4f,4p)$	-2764.8	-64.0	-3476.4	0.795
$4s^26g$-$4s4p4f$	$R^1(4s,6g;4p,4f)$	-10935.7	-252.0	-13749.9	0.795
	$R^3(4s,6g;4f,4p)$	-2565.1	-59.0	-3225.2	0.795
$4s^27g$-$4s4p4f$	$R^1(4s,7g;4p,4f)$	-8313.1	-191.0	-10452.4	0.795
	$R^3(4s,7g;4f,4p)$	-2210.4	-51.0	-2779.2	0.795
$4s^28g$-$4s4p4f$	$R^1(4s,8g;4p,4f)$	-6608.9	-152.0	-8309.6	0.795
	$R^3(4s,8g;4f,4p)$	-1889.8	-43.0	-2376.2	0.795
$4p^24d$-$4p^25s$	$R^2(4p,4d;4p,5s)$	-7237.0	-167.0	-9099.4	0.795
	$R^1(4p,4d;5s,4p)$	-1214.5	-28.0	-1527.0	0.795
$4p^24d$-$4s4p5p$	$R^1(4p,4d;4s,5p)$	-1769.8	-41.0	-2225.3	0.795
	$R^2(4p,4d;5p,4s)$	6030.3	139.0	7582.1	0.795
$4p^24d$-$4s4p4f$	$R^1(4p,4d;4s,4f)$	37865.8	1177.0	46064.4	0.822
	$R^2(4p,4d;4f,4s)$	22428.9	697.0	27285.1	0.822
$4p^25s$-$4s4p5p$	$R^1(4p,5s;4s,5p)$	28956.6	900.0	35226.3	0.822
	$R^0(4p,5s;5p,4s)$	4266.1	98.0	5363.9	0.795
$4s4p5p$-$4s4p4f$	$R^2(4p,5p;4p,4f)$	-6915.9	-159.0	-8695.6	0.795
	$R^2(4p,5p;4f,4p)$	1976.9	45.0	2485.6	0.795
	Standard deviation σ	360.0			

he configuration interaction integrals for known configurations were linked to vary in the same ratio; the
:maining integrals fixed at 80% were not included in the table.

CHAPTER 6

The sixth spectrum of bromine: Br VI

The five-times ionized bromine (Br VI) has neutral zinc- like (Zn I) structure with $4s^2$ as the ground state configuration. Most of the excited configurations are of the type $3d^{10}\,4s\,n\ell$ ($n \geq 4$) but the core excitation gives $3d^9 4s^2$ (4p + 4f). The further excitations lead to $4p^2$, 4p4d, and 4p5s. The spectral data on ionized atoms are always important for plasma diagnostics as well as for spectroscopic database. Consequently, this sequence has also been studied extensively [1-16]. Rao and Rao [8] reported 10 levels in Br VI from the low excited configurations 4s4p, 4s4d and $4p^2$ which was followed by Joshi and Van Kleef [9], Churilov et al [10] and finally by Churilov and Joshi [11] covering the configurations $3d^{10}4s^2$, $3d^{10}4s$(4p+5p+ 5s+4d+4f) and $4p^2$, 4p(4d+5s). In the present work, all the levels reported by Churilov et al [10] were confirmed which shows that none of the Rao and Rao's level could be verified except 4s4p $^1P_1$. Also, 4s5p $^3P_0$ and $4p^2$ $^1S_0$ of Joshi and van Kleef [9] were revised. Churilov and Joshi [11] reported 17 new levels based on lines identification in the 400 – 1200Å wavelength region arising out of transitions between $4s^2$ - (4s4p+4s5p), $4p^2$ - (4p4d+4p5s), 4s4d - (4s5p+4s4f) and 4s5s - (4s5p+4p5s).

The present investigation was undertaken mainly due to the availability of more precise and extended data on bromine spectrum which lead us to extend the study of new configurations $3d^{10}4s$(6s, 7s, 8s, 6p, 7p, 5d, 6d, 5f, 5g, 6g).

6.1 The energy level structure:

The electronic distribution for ground configuration of five times ionized Bromine (Br VI) is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$. It gives $^1S_0$ as the ground level of the ion.

The excited configurations of our interest along with the resulting levels are given as follows:

4snp:	$^3P_{0,1,2}$, $^1P_1$	($n \geq 4$)
4snd:	$^3D_{1,2,3}$, $^1D_2$	($n \geq 4$)
4sns:	$^3S_1$, $^1S_0$	($n \geq 5$)
4snf:	$^3F_{2,3,4}$, $^1F_3$	($n \geq 4$)
$4p^2$:	$^3P_{0,1,2}$, $^1S_0$, $^1D_2$	
4p4d:	$^3P_{0,1,2}$, $^3D_{1,2,3}$, $^3F_{2,3,4}$, $^1P_1$, $^1D_2$, $^1F_3$	
4p5s:	$^3P_{0,1,2}$, $^1P_1$	
$3d^9 4s^2 4p$:	$^3P_{0,1,2}$, $^3D_{1,2,3}$, $^3F_{2,3,4}$, $^1P_1$, $^1D_2$, $^1F_3$	
$3d^9 4s^2 4f$:	$^3P_{0,1,2}$, $^3D_{1,2,3}$, $^3F_{2,3,4}$, $^3G_{3,4,5}$, $^3H_{4,5,6}$, $^1P_1$, $^1D_2$, $^1F_3$, $^1G_4$, $^1H_5$	

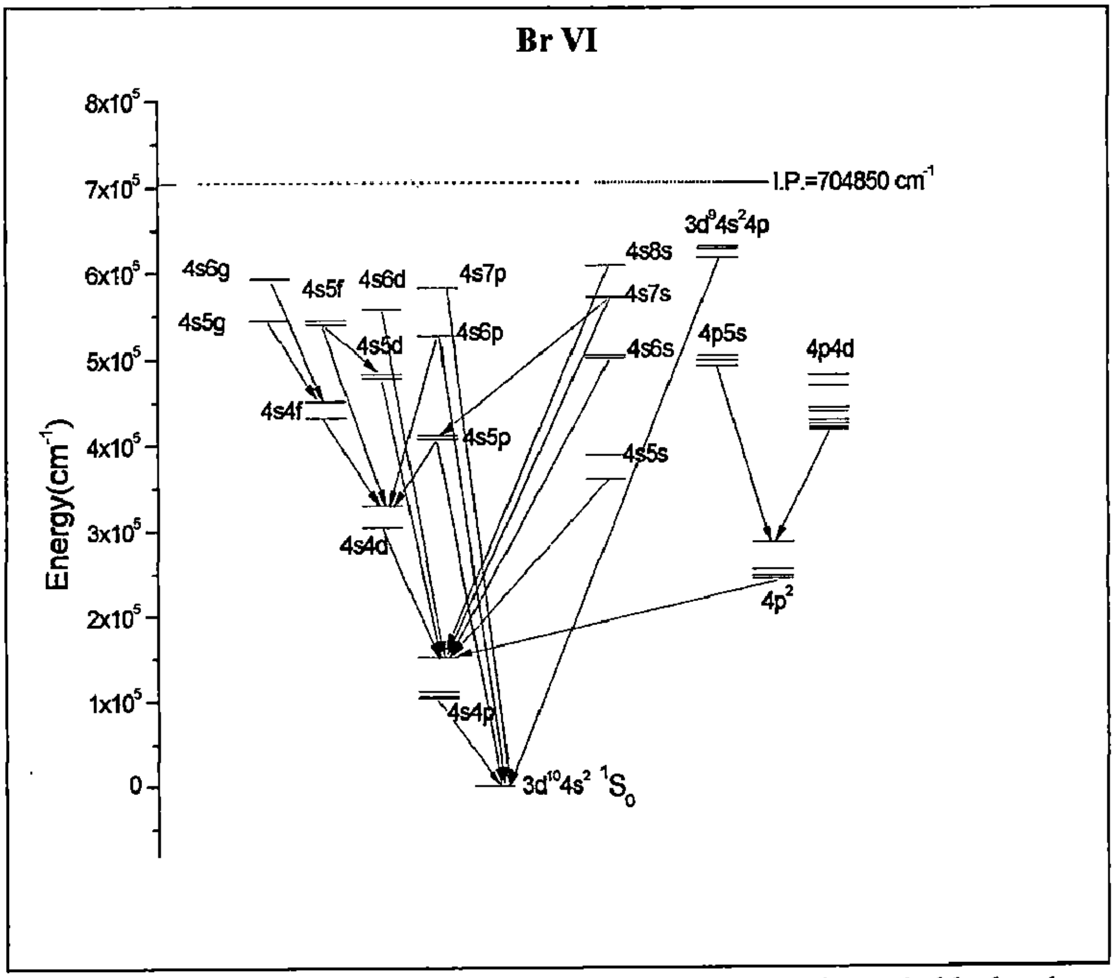

Fig. 6.1: Energy level diagram of Br VI. The configurations shown in black colour are analyzed in earlier work [9-11,18] and that shown in red colour are studied in the present work.

6.2 Theoretical calculations:

The theoretical prediction for this spectrum was obtained by using Cowan's code [17] in HFR mode. The configurations included for even parity matrix were $3d^{10}4s^2$, $4p^2$, 4snd (n=4-6), 4sns (n=5-8), 4sng (n=5-7) and that for odd parity system were 4snp (n=4-7), 4snf (n=4-6), 4p4d, 4p5s, $3d^94s^24p$ and $3d^94s^24f$. The *ab initio* values of the energy parameters were initially scaled using scaling factors from its isoelectronic members Ge III [14] and As IV [15] as well as Kr VII [16]. Soon it was noticed that 4s7g and $3d^94s^24f$ were not showing significant interactions with other configurations and were therefore, dropped from final least squares fitted calculations. In fact $3d^94s^24f$ configuration lies above the ionization limit. As the analysis progressed the calculations were refined by determining empirical values for the energy parameters from least-squares fits to the experimental level values.

6.3 Analysis and discussions:

The observed transitions were found to confirm all previously reported levels by Churilov and Joshi [11] except 4p4d $^3F_4$ and 4p4d $^1D_2$. The problem with 4p4d $^3F_4$ was that the only permitted transition from 4s4d $^3D_3$ could not be seen on our plates. Therefore, a new line at 846.976 Å, showing Br VI characteristic on our plates was assigned as 4s4d $^3D_3$ – 4p4d $^3F_4$ transition which yielded the new level value of 4p4d $^3F_4$ at 422807.7 cm^{-1}. The reported 4p4d $^1D_2$ level at 427619 cm^{-1} did not give any corresponding transition. Further, from their reported transitions, the average derived level value of 4p4d $^1D_2$ should have been 426500 cm^{-1}. This level value did not fit in the least squares fitted parametric calculations, showing large deviation. Moreover, the lines which were used to establish this level did not give Br VI characteristics. We found two lines at 551.688 and 552.347 Å with moderate intensities and Br VI character to establish this level at 427734.5 cm^{-1} which fitted nicely with expected scaling factor of the energy parameters.

The line at 799.193Å, earlier classified as $4p^2$ $^1S_0$ - 4s5p $^1P_1$ with weak calculated relative transition probability [11] was found quite strong on our plates and does not belong to Br VI ionization character rather appearing more like Br III. However, the other lines at 243.336, 607.964, 633.809 and 1230.318 Å belonging to Br VI have been classified as transitions from 4s5p $^1P_1$, supporting the level identification. The line at 389.578 Å ($4p^2$ $^1D_2$ - 4p5s $^1P_1$) reported doubtful in Ref.

[11], has now been confirmed as a Br VI line. This is in fact a blended line which is doubly classified and we confirm the earlier classification 4s4p $^3P_0$ – 4s5s $^3S_1$ as well.

For new configurations $3d^{10}4s$(6s,7s, 8s, 6p,7p, 5d, 6d, 5f ,5g & 6g), more precise level values were obtained by comparing the parameter's variation in Ga II – As IV [13-15]. The newly established levels are fitting nicely in the least-squares fitted (LSF) parametric calculations with expected scaling factors (LSF/HFR) of the corresponding parameters. It should be pointed out that due to heavy admixture of 4p4d ^3F in 4s4f ^3F level as well as the significant interaction between $4p^2$ and 4s4d configurations, the transitions between $4p^2$ and 4s4f are also observed. In fact 4s4f ^1F is so strongly mixed with 4p4d ^1F level that their compositions are 58% 4p4d and 38% 4s4f as well as 60% 4s4f and 37% 4p4d (see Table 6.2). This trend continues in higher members of the isoelectronic sequence [10]. The other non electric dipole transitions were also observed from 4p4d to (4s5g, 4s6g, 4s5d, 4s6d) configurations.

6.4 Results:

One hundred and fifty-eight spectral lines have been classified in this spectrum, out of which 69 are newly classified. All these lines are listed in Table 6.1 along with their calculated transition probabilities (gA) and weighted oscillator strength (gf). Two lines are doubly classified. Sixty-eight levels have been established out of which 28 are new. A least-square fitting program "KLAS" based on matrix inversion method was used to optimize the energy level values from the observed transitions. The higher weighting factors were given to the longer wavelengths. The level uncertainty for majority of the levels as obtained by KLAS output, was found to be between 0.2 - 0.9 cm^{-1}. Three levels of internally excited configuration, namely $3d^94s^24p$ ($^3D_1$, $^1P_1$, & $^3P_1$) established through the transitions from ground state, are based on very short wavelengths (158.635, 159.388 & 161.862Å) and they may be uncertain up to 10 cm^{-1}. The LSF energy levels of Br VI along with their LS-percentage compositions are given in Table 6.2. For the sake of completeness, the previously reported levels are also included in Table 6.2. The corresponding least squares fitted energy parameters are given in Table 6.3. The agreement with theoretical calculations was found to be quite good as evident from Table 6.2. The standard deviation for even and odd parity configurations are 64 and 117 cm^{-1} respectively. The LS purity of all the established levels is greater than 50%, consequently, LS designation was assigned to the established levels without ambiguity. Finally, the variation of the energy parameter's ratio (LSF/HFR) was compared with isoelectronic ions Ga II – Kr VII [13-16] and was found to be satisfactory.

A Grotorian energy level diagram of Br VI has been shown in Fig. 6.1.

6.41 Ionization potential:

Three member series 4sns (n=5-8) have been observed in Br VI which led us to determine the ionization limit of this spectrum. Though 4sng (n=5-7) series is more desirable for better accuracy but unfortunately only two series members are known at the moment. However, it was noticed in its isoelectronic members Zn I [12] and Ga II [13] that limit obtained by 4sng series is in close agreement with that found by 4sns series. We therefore, estimated ionization potential from 4sns series using Ritz's formula. The adapted value of series limit for Br VI is 704850 ± 200 cm^{-1} (87.390 ± 0.025eV).

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Table 6.1: Classified lines of Br VI.

λ(Å)	ν(cm^{-1})	Int[e]	Classification	Δλ(Å)[f]	log gf	gA (s^{-1})[g]
158.635[d]	630377.0	25	$4s^2\ ^1S_0$ - $d^94p^+\ ^3D_1$	0.000	-1.295	1.35E+10
159.388[d]	627399.0	60	$4s^2\ ^1S_0$ - $d^94p^+\ ^1P_1$	0.000	-0.242	1.50E+11
161.862	617810.1	4	$4s^2\ ^1S_0$ - $d^94p^+\ ^3P_1$	0.000	-1.772	4.30E+09
171.498	583098.4	13	$4s^2\ ^1S_0$ - $4s7p\ ^1P_1$	0.000	-1.791	4.06E+09
189.804	526860.6	39	$4s^2\ ^1S_0$ - $4s6p\ ^1P_1$	0.000	-1.743	5.66E+09
200.634	498419.0	5	$4s4p\ ^3P_2$ - $4s8s\ ^3S_1$	0.000	-1.583	4.32E+09
215.289	464492.0	17	$4s4p\ ^3P_1$ - $4s7s\ ^3S_1$	-0.001	-1.609	3.54E+09
217.590	459579.0	25	$4s4p\ ^3P_2$ - $4s7s\ ^3S_1$	-0.001	-1.39	5.74E+09
238.056	420068.9	12	$4s4p\ ^1P_1$ - $4s7s\ ^1S_0$	0.000	-1.554	3.29E+09
243.336[c]	410954.4	78	$4s^2\ ^1S_0$ - $4s5p\ ^1P_1$	-0.001	-1.292	5.75E+09
251.405	397764.8	42	$4s4p\ ^3P_0$ - $4s6s\ ^3S_1$	0.002	-1.648	2.37E+09
252.748	395650.9	56	$4s4p\ ^3P_1$ - $4s6s\ ^3S_1$	-0.001	-1.176	6.97E+09
255.928	390735.3	60	$4s4p\ ^3P_2$ - $4s6s\ ^3S_1$	0.001	-0.957	1.13E+10
266.776	374846.7	10	$4s4p\ ^3P_0$ - $4s5d\ ^3D_1$	0.001	-1.912	1.15E+09
268.297	372721.9	9	$4s4p\ ^3P_1$ - $4s5d\ ^3D_1$	0.006	-2.042	8.43E+08
271.571	368227.6	19	$4s4p\ ^3P_2$ - $4s5d\ ^3D_3$	0.000	-1.295	4.59E+09
283.533	352692.9	36	$4s4p\ ^1P_1$ - $4s6s\ ^1S_0$	-0.001	-1.162	5.72E+09
302.535	330539.7	8	$4s4p\ ^1P_1$ - $4s5d\ ^1D_2$	-0.003	-1.003	7.23E+09
389.575[c]	256690.2	45	$4s4p\ ^3P_0$ - $4s5s\ ^3S_1$	0.002	-0.859	6.07E+09
389.575[a]			$4p^2\ ^1D_2$ - $4p5s\ ^1P_1$	0.002	-0.348	1.94E+10
392.813[c]	254574.3	50	$4s4p\ ^3P_1$ - $4s5s\ ^3S_1$	-0.001	-0.388	1.77E+10
397.377[b]	251650.1	8	$4p^2\ ^1D_2$ - $4p5s\ ^3P_2$	-0.003	-0.592	1.08E+10
397.720[b]	251432.9	10	$4p^2\ ^3P_1$ - $4p5s\ ^3P_2$	0.000	-0.512	1.30E+10
400.545[c]	249660.0	70	$4s4p\ ^3P_2$ - $4s5s\ ^3S_1$	0.002	-0.173	2.79E+10
402.496[b]	248449.7	7	$4p^2\ ^3P_0$ - $4p5s\ ^3P_1$	0.001	-0.633	9.58E+09
407.510[b]	245392.7	13	$4p^2\ ^1D_2$ - $4p5s\ ^3P_1$	0.006	-0.496	1.28E+10
407.864[b]	245180.0	6	$4p^2\ ^3P_1$ - $4p5s\ ^3P_1$	0.002	-0.821	6.06E+09
408.260[b]	244941.7	20	$4p^2\ ^3P_2$ - $4p5s\ ^3P_2$	0.002	-0.196	2.55E+10
409.481[b]	244211.8	10	$4p^2\ ^3P_1$ - $4p5s\ ^3P_0$	-0.004	-0.637	9.17E+09
414.866	241042.0	12	$4p^2\ ^1S_0$ - $4s6p\ ^1P_1$	0.000	-1.529	1.15E+09
422.598	236631.5	3	$4s4d\ ^3D_1$ - $4s5f\ ^3F_2$	0.009	-0.794	6.01E+09
423.176	236308.5	6	$4s4d\ ^3D_2$ - $4s5f\ ^3F_3$	0.006	-0.62	8.94E+09
424.023	235836.5	10	$4s4d\ ^3D_3$ - $4s5f\ ^3F_4$	0.001	-0.456	1.30E+10
427.347[a]	234001.8	25	$4p^2\ ^1D_2$ - $4p4d\ ^1F_3$	-0.006	-0.001	3.64E+10
439.958	227294.5	5	$4p^2\ ^3P_2$ - $4p4d\ ^1F_3$	-0.002	-0.349	1.54E+10
458.363	218167.9	30	$4s4d\ ^3D_3$ - $4s6p\ ^3P_2$	0.010	-0.815	4.86E+09
460.678[c]	217071.5	50	$4s4p\ ^1P_1$ - $4s5s\ ^1S_0$	-0.002	-0.404	1.24E+10
465.192	214965.0	30	$4s4d\ ^1D_2$ - $4s5f\ ^1F_3$	-0.002	-0.048	2.76E+10
478.466[c]	209001.5	3	$4s4p\ ^1P_1$ - $4s5s\ ^3S_1$	-0.001	-2.761	5.05E+07
485.322	206048.6	3	$4p^2\ ^1S_0$ - $4p5s\ ^3P_1$	0.005	-1.582	7.42E+08
499.183[c]	200327.5	50	$4s4p\ ^3P_0$ - $4s4d\ ^3D_1$	-0.003	0.045	2.97E+10
503.712[c]	198526.1	55	$4s4p\ ^3P_1$ - $4s4d\ ^3D_2$	0.000	0.392	6.48E+10
504.515[c]	198210.1	40	$4s4p\ ^3P_1$ - $4s4d\ ^3D_1$	-0.006	-0.087	2.15E+10
505.611[a]	197780.5	2	$4p^2\ ^3P_2$ - $4s4f\ ^3F_3$	0.006	-1.362	1.13E+09
507.131	197187.5	22	$4s4d\ ^1D_2$ - $4s6p\ ^1P_1$	0.000	-0.824	3.89E+09
508.570[a]	196629.9	25	$4p^2\ ^1D_2$ - $4p4d\ ^3D_2$	-0.001	-0.082	2.13E+10
508.956[a]	196480.6	30	$4p^2\ ^1D_2$ - $4p4d\ ^3D_3$	0.007	0.2	4.07E+10
509.129[a]	196413.8	35	$4p^2\ ^3P_1$ - $4p4d\ ^3D_2$	0.002	-0.014	2.49E+10
509.577[a]	196241.1	15	$4p^2\ ^1D_2$ - $4p4d\ ^3P_1$	0.002	-0.619	6.18E+09
510.137[b]	196025.8	25	$4p^2\ ^3P_1$ - $4p4d\ ^3P_1$	0.002	0.183	3.91E+10
511.358[a]	195557.6	20	$4p^2\ ^3P_1$ - $4p4d\ ^3P_0$	-0.004	-0.17	1.73E+10
513.243[a]	194839.5	40	$4p^2\ ^3P_0$ - $4p4d\ ^3D_1$	-0.004	0.383	6.12E+10
515.156[c]	194115.9	75	$4s4p\ ^3P_2$ - $4s4d\ ^3D_3$	-0.002	0.653	1.13E+11
516.482[c]	193617.5	70	$4s4p\ ^3P_2$ - $4s4d\ ^3D_2$	-0.010	-0.095	2.01E+10

517.338[c]	193297.2	35	4s4p $^3P_2$ - 4s4d $^3D_1$	-0.004	-1.272	1.33E+09
522.009[a]	191567.7	10	$4p^2$ $^3P_1$ - 4p4d $^3D_1$	0.003	-0.54	7.06E+09
522.265[a]	191473.5	37	$4p^2$ $^3P_1$ - 4p4d $^3P_2$	0.003	0.55	8.69E+10
526.526[a]	189924.3	50	$4p^2$ $^3P_2$ - 4p4d $^3D_2$	0.001	0.42	6.32E+10
526.932[a]	189777.7	45	$4p^2$ $^3P_2$ - 4p4d $^3D_3$	0.002	0.736	1.31E+11
527.598[b]	189538.3	20	$4p^2$ $^3P_2$ - 4p4d $^3P_1$	-0.004	-0.222	1.44E+10
540.268[a]	185093.3	35	$4p^2$ $^1D_2$ - 4s4f $^1F_3$	-0.001	0.555	8.20E+10
540.595[a]	184981.3	18	$4p^2$ $^3P_2$ - 4p4d $^3P_2$	0.010	-0.412	8.86E+09
549.581[a]	181956.7	40	$4p^2$ $^1S_0$ - 4p4d $^1P_1$	0.005	0.391	5.44E+10
551.688	181261.9	30	$4p^2$ $^1D_2$ - 4p4d $^1D_2$	-0.002	0.353	4.94E+10
552.347	181045.7	10	$4p^2$ $^3P_1$ - 4p4d $^1D_2$	0.002	-0.829	3.24E+09
560.582[b]	178386.0	35	4s4p $^1P_1$ - 4s4d $^1D_2$	0.007	0.723	1.12E+11
560.582[a]			$4p^2$ $^3P_2$ - 4s4f $^1F_3$	0.007	-0.108	1.66E+10
567.271	176282.6	8	4p4d $^3F_2$ - 4s6g $^3G_3$	0.002	-0.8	3.29E+09
585.892[a]	170679.8	15	$4p^2$ $^1D_2$ - 4p4d $^3F_2$	0.005	0.956	2.15E+09
607.973[b]	164481.1	6	$4p^2$ $^1D_2$ - 4s5p $^1P_1$	-0.006	-0.667	3.88E+09
614.095	162841.3	2	4s5p $^3P_1$ - 4s7s $^3S_1$	0.000	-1.02	1.69E+09
614.900	162628.2	3	4s5s $^3S_1$ - 4s6p $^3P_2$	-0.006	-2.868	2.39E+07
616.541[c]	162195.1	20	4s4d $^1D_2$ - 4p5s $^3P_1$	0.005	-1.247	9.95E+08
621.561[b]	160885.3	5	$4p^2$ $^1D_2$ - 4s5p $^3P_1$	0.007	-1.823	2.60E+08
624.041[a]	160246.0	3	$4p^2$ $^3P_1$ - 4s5p $^3P_0$	-0.001	-3.75	3.04E+06
633.809	157776.3	7	$4p^2$ $^3P_2$ - 4s5p $^1P_1$	-0.006	-1.023	1.58E+09
653.788[c]	152954.7	5	4s4p $^1P_1$ - 4s4d $^3D_2$	-0.005	-2.351	6.96E+07
655.146[c]	152637.7	3	4s4p $^1P_1$ - 4s4d $^3D_1$	-0.009	-2.495	4.97E+07
661.005	151284.7	85	$4s^2$ $^1S_0$ - 4s4p $^1P_1$	0.001	0.266	2.82E+10
662.814	150871.9	10	4s5p $^3P_0$ - 4s6d $^3D_1$	-0.012	-1.496	4.84E+08
663.140[a]	150797.7	35	4s4d $^1D_2$ - 4p4d $^1F_3$	0.004	1.065	1.76E+11
664.621	150461.8	13	4s5p $^3P_1$ - 4s6d $^3D_2$	-0.005	-1.156	1.05E+09
670.744	149088.2	14	4s5p $^3P_2$ - 4s6d $^3D_3$	0.000	-0.878	1.96E+09
671.288	148967.3	3	4s5p $^3P_2$ - 4s6d $^3D_2$	0.005	-1.628	3.49E+08
678.127[c]	147465.1	65	4s4p $^3P_1$ - $4p^2$ $^3P_2$	0.002	-0.276	7.68E+09
681.348[a]	146767.9	30	4s4d $^3D_1$ - 4s4f $^3F_2$	0.005	0.709	7.34E+10
681.558[a]	146722.7	37	4s4d $^3D_2$ - 4s4f $^3F_3$	-0.001	0.883	1.10E+11
682.119[a]	146602.0	40	4s4d $^3D_3$ - 4s4f $^3F_4$	0.010	1.036	1.56E+11
682.830[a]	146449.3	8	4s4d $^3D_2$ - 4s4f $^3F_2$	0.008	-0.117	1.09E+10
683.881[a]	146224.3	10	4s4d $^3D_3$ - 4s4f $^3F_3$	-0.014	-0.173	9.57E+09
685.165	145950.2	67	4s4d $^3D_3$ - 4s4f $^3F_2$	-0.003	-1.736	2.61E+08
698.841[c]	143094.1	70	4s4p $^3P_0$ - $4p^2$ $^3P_1$	0.001	-0.197	8.67E+09
700.533	142748.4	3	4s4f $^3F_2$ - 4s6g $^3G_3$	-0.001	-0.091	1.10E+10
701.490[c]	142553.8	75	4s4p $^3P_2$ - $4p^2$ $^3P_2$	-0.001	0.231	2.31E+10
701.871	142476.3	3	4s4f $^3F_3$ - 4s6g $^3G_4$	0.001	0.013	1.40E+10
703.556	142135.1	5	4s4f $^3F_4$ - 4s6g $^3G_5$	0.000	0.115	1.75E+10
703.760	142093.9	2	4s4f $^3F_4$ - 4s6g $^3G_4$	-0.001	-1.176	8.96E+08
709.345[c]	140975.2	70	4s4p $^3P_1$ - $4p^2$ $^3P_1$	0.003	-0.331	6.19E+09
710.426[b]	140760.7	62	4s4p $^3P_1$ - $4p^2$ $^1D_2$	0.000	-0.552	3.71E+09
718.487[a]	139181.3	52	4s4d $^3D_1$ - 4p4d $^3D_2$	0.006	-0.866	1.76E+09
720.119[a]	138865.9	28	4s4d $^3D_2$ - 4p4d $^3D_2$	-0.007	0.178	1.94E+10
720.484[b]	138795.7	12	4s4d $^3D_1$ - 4p4d $^3P_1$	-0.005	-0.045	1.16E+10
720.882[a]	138718.9	3	4s4d $^3D_2$ - 4p4d $^3D_3$	-0.004	-1.087	1.05E+09
722.149[b]	138475.5	8	4s4d $^3D_2$ - 4p4d $^3P_1$	0.005	-0.551	3.60E+09
722.943[a]	138323.5	13	4s4d $^3D_1$ - 4p4d $^3P_0$	0.002	-0.372	5.43E+09
723.499[a]	138217.2	35	4s4d $^3D_3$ - 4p4d $^3D_3$	-0.001	0.338	2.76E+10
724.088[a]	138104.8	6	4s4d $^1D_2$ - 4p4d $^1P_1$	-0.003	0.151	1.80E+10
725.504[b]	137835.3	14	4s5s $^3S_1$ - 4p5s $^3P_2$	0.000	0.31	2.59E+10
726.179[c]	137707.0	75	4s4p $^3P_1$ - $4p^2$ $^3P_0$	-0.003	-0.216	7.68E+09
734.951[c]	136063.5	80	4s4p $^3P_2$ - $4p^2$ $^3P_1$	0.002	-0.124	9.29E+09
736.119[b]	135847.5	55	4s4p $^3P_2$ - $4p^2$ $^1D_2$	0.006	-0.199	7.79E+09

741.788[a]	134809.4	60	4s5s $^1S_0$ - 4p5s $^1P_1$	-0.001	0.131	1.60E+10
743.312[a]	134533.0	90	4s4p $^1P_1$ - $4p^2$ $^1S_0$	0.005	-0.171	8.14E+09
744.399[a]	134336.5	3	4s4d $^3D_1$ - 4p4d $^3D_1$	-0.000	-0.848	1.71E+09
744.917[a]	134243.2	2	4s4d $^3D_1$ - 4p4d $^3P_2$	-0.004	-1.881	1.58E+08
746.166[a]	134018.5	20	4s4d $^3D_2$ - 4p4d $^3D_1$	0.000	-0.049	1.07E+10
749.493[a]	133423.4	30	4s4d $^3D_3$ - 4p4d $^3P_2$	-0.002	0.24	2.07E+10
759.966[b]	131584.9	70	4s5s $^3S_1$ - 4p5s $^3P_1$	-0.008	0.012	1.19E+10
765.628[b]	130611.8	3	4s5s $^3S_1$ - 4p5s $^3P_0$	0.001	-0.407	4.46E+09
785.372	127328.2	2	4s4d $^3D_2$ - 4s4f $^1F_3$	-0.003	-3.98	1.13E+06
785.451	127315.4	1	4p4d $^3F_2$ - 4s5g $^3G_3$	-0.006	-0.145	7.74E+09
800.477	124925.5	3	4p4d $^3F_3$ - 4s5g $^3G_4$	0.000	0.046	1.16E+10
821.895	121670.1	5	4p4d $^3F_4$ - 4s5g $^3G_5$	0.006	0.268	1.83E+10
846.976	118067.1	10	4s4d $^3D_3$ - 4p4d $^3F_4$	0.006	-0.971	1.54E+09
867.243[a]	115308.0	7	4s4d $^3D_2$ - 4p4d $^3F_3$	0.003	-0.939	1.02E+09
871.024[a]	114807.4	3	4s4d $^3D_3$ - 4p4d $^3F_3$	-0.003	-1.203	5.51E+08
883.120	113234.9	10	4s4d $^3D_1$ - 4p4d $^3F_2$	-0.007	-0.948	9.63E+08
885.615[a]	112915.9	5	4s4d $^3D_2$ - 4p4d $^3F_2$	0.001	-1.305	4.21E+08
933.591	107113.3	2	4s4f $^3F_2$ - 4s6d $^3D_1$	0.006	-2.167	5.21E+07
934.289	107033.3	8	4s4d $^3D_1$ - 4s5p $^1P_1$	-0.008	-1.825	1.14E+08
937.074	106715.2	18	4s4d $^3D_2$ - 4s5p $^1P_1$	-0.008	-1.468	2.59E+08
945.960[c]	105712.7	100	$4s^2$ $^1S_0$ - 4s4p $^3P_1$	-0.001	-2.193	4.78E+07
955.883[c]	104615.3	40	4s4d $^3D_2$ - 4s5p $^3P_2$	-0.009	-0.609	1.80E+09
966.753[c]	103439.0	55	4s4d $^3D_1$ - 4s5p $^3P_1$	0.010	-0.636	1.65E+09
969.735[c]	103121.0	70	4s4d $^3D_2$ - 4s5p $^3P_1$	0.009	-0.163	4.88E+09
970.738[a]	103014.4	60	4s4d $^3D_1$ - 4s5p $^3P_0$	-0.007	-0.49	2.29E+09
981.423[c]	101892.8	90	4s4p $^1P_1$ - $4p^2$ $^3P_2$	0.004	-0.6	1.74E+09
1048.179	95403.6	5	4s4p $^1P_1$ - $4p^2$ $^3P_1$	-0.001	-2.797	9.70E+06
1050.548	95188.4	100	4s4p $^1P_1$ - $4p^2$ $^1D_2$	0.000	-0.275	3.21E+09
1063.815	94001.3	50	4s5p $^3P_1$ - 4s6s $^3S_1$	0.000	-0.202	3.70E+09
1069.382	93512.0	15	4s4f $^3F_3$ - 4s5g $^3G_4$	-0.008	0.835	3.98E+10
1069.432	93507.6	8	4s4f $^3F_3$ - 4s5g $^3G_3$	0.003	-0.341	2.66E+09
1073.708	93135.2	20	4s4f $^3F_4$ - 4s5g $^3G_5$	-0.004	0.94	5.03E+10
1073.793	93127.9	5	4s4f $^3F_4$ - 4s5g $^3G_4$	0.008	-0.351	2.57E+09
1074.992	93024.0	15	4s5p $^1P_1$ - 4s6s $^1S_0$	0.000	-0.238	3.34E+09
1085.377[c]	92133.9	40	4s4p $^1P_1$ - $4p^2$ $^3P_0$	0.001	-2.431	2.10E+07
1230.318	81279.8	7	4s4d $^1D_2$ - 4s5p $^1P_1$	0.000	-0.072	3.73E+09
1343.005	74459.9	15	4s5p $^3P_1$ - 4s5d $^1D_2$	0.011	-0.768	6.30E+08
1398.429	71508.8	35	4s5p $^3P_0$ - 4s5d $^3D_1$	-0.001	0.153	4.86E+09
1399.153	71471.8	40	4s5p $^3P_1$ - 4s5d $^3D_2$	0.002	0.488	1.04E+10
1411.062	70868.6	45	4s5p $^1P_1$ - 4s5d $^1D_2$	-0.009	0.59	1.30E+10
1428.590	69999.1	50	4s5p $^3P_2$ - 4s5d $^3D_3$	0.000	0.765	1.90E+10
1428.987	69979.6	20	4s5p $^3P_2$ - 4s5d $^3D_2$	-0.002	0.015	3.37E+09
1591.949	62816.1	12	4s5d $^1D_2$ - 4s5f $^1F_3$	0.000	0.85	1.86E+10
1609.936	62114.3	8	4s5d $^3D_1$ - 4s5f $^3F_2$	-0.001	0.645	1.13E+10
1620.087	61725.1	25	4s5d $^3D_3$ - 4s5f $^3F_4$	0.000	0.973	2.39E+10
1620.270	61718.1	15	4s5d $^3D_2$ - 4s5f $^3F_3$	0.000	0.813	1.66E+10
2059.017	48566.9	5	4s5s $^3S_1$ - 4s5p $^3P_2$	0.001	0.31	3.22E+09

[a] Churilov & Joshi Ref.[11], [b] Ref[10], [c] Ref.[9], [d] Ref.[18].

[e] Intensity figures are visual estimates of photographic blackening.

[f] Observed wavelength value-calculated value from levels in Table 6.2

[g] Transition probabilities (gA) obtained by Cowan's code. Here g is the statistical weight of the upper level while for gf, g refers to the statistical weight of the lower level.

[+] d^94p stands for $3d^94s^24p$.

Table 6.2: Observed and LSF energy levels of Br VI in cm^{-1}.

J	E(obs)	E(LSF)	diff.	LS-composition.
Even configuration				
0	0.0	0.0	0.0	98% $3d^{10}4s^2$
	243418.9[a]	243403.0	15.9	98% $3d^{10}4p^2$ ^3P
	285818.8[a]	285819.0	-0.2	96% $3d^{10}4p^2$ ^1S
	368355.7[a]	368356.0	-0.3	100% $3d^{10}4s5s$ ^1S
	503976.8	503977.0	-0.2	100% $3d^{10}4s6s$ ^1S
	571353.9	571354.0	-0.1	100% $3d^{10}4s7s$ ^1S
	-	609857.0	-	100% $3d^{10}4s8s$ ^1S
1	246688.4[a]	246710.0	-21.6	100% $3d^{10}4p^2$ ^3P
	303920.5[a]	303919.0	1.5	100% $3d^{10}4s4d$ ^3D
	360285.9[a]	360286.0	-0.1	100% $3d^{10}4s5s$ ^3S
	478442.9	478570.0	-127.1	100% $3d^{10}4s5d$ ^3D
	501361.8	501362.0	-0.2	100% $3d^{10}4s6s$ ^3S
	557803.4	557783.0	20.4	100% $3d^{10}4s6d$ ^3D
	570201.8	570202.0	-0.2	100% $3d^{10}4s7s$ ^3S
	609043.6	609044.0	-0.4	100% $3d^{10}4s8s$ ^3S
2	246473.3[a]	246477.0	-3.7	62% $3d^{10}4p^2$ ^1D +28%$3d^{10}4p^2$ ^3P +10%$3d^{10}4s4d$ ^1D
	253178.2[a]	253168.0	10.2	72% $3d^{10}4p^2$ ^3P +23%$3d^{10}4p^2$ ^1D +5%$3d^{10}4s4d$ ^1D
	304238.5[a]	304242.0	-3.5	100% $3d^{10}4s4d$ ^3D
	329673.0[a]	329673.0	0.0	85% $3d^{10}4s4d$ ^1D +15%$3d^{10}4p^2$ ^1D
	478832.4	478684.0	148.4	100% $3d^{10}4s5d$ ^3D
	481821.0	481821.0	0.0	99% $3d^{10}4s5d$ ^1D
	557821.2	557842.0	-20.8	100% $3d^{10}4s6d$ ^3D
	-	559416.0	-	99% $3d^{10}4s6d$ ^1D
3	304739.8[a]	304739.0	0.8	100% $3d^{10}4s4d$ ^3D
	478851.9	478872.0	-20.1	100% $3d^{10}4s5d$ ^3D
	544469.0	544471.0	-2.0	100% $3d^{10}4s5g$ ^3G

	557941.0	557940.0	1.0	100% $3d^{10}4s6d\ ^3D$
	593437.6	593450.0	-12.4	100% $3d^{10}4s6g\ ^3G$
4	544472.4	544473.0	-0.6	100% $3d^{10}4s5g\ ^3G$
	-	544719.0	-	100% $3d^{10}4s5g\ ^1G$
	593437.6	593451.0	-13.4	100% $3d^{10}4s6g\ ^3G$
	-	593650.0	-	100% $3d^{10}4s6g\ ^1G$
5	544478.7	544476.0	2.7	100% $3d^{10}4s5g\ ^3G$
	593479.0	593453.0	26.0	100% $3d^{10}4s6g\ ^3G$
Odd Configuration				
0	103594.2[a]	103601.0	-6.8	100% $3d^{10}4s4p\ ^3P$
	406934.1[a]	406930.0	4.1	99% $3d^{10}4s5p\ ^3P$
	442244.3[a]	442391.0	-146.7	99% $3d^{10}4p4d\ ^3P$
	490897.9[a]	490845.0	52.9	99% $3d^{10}4p5s\ ^3P$
	-	521863.0	-	100% $3d^{10}4s6p\ ^3P$
	-	581462.0	-	100% $3d^{10}4s7p\ ^3P$
	-	622552.0	-	100% $3d^{9}4s^{2}4p\ ^3P$
1	105712.6[a]	105703.0	9.6	99% $3d^{10}4s4p\ ^3P$
	151285.0[a]	151282.0	3.0	98% $3d^{10}4s4p\ ^1P$
	407360.5[a]	407364.0	-3.5	93% $3d^{10}4s5p\ ^3P$ + 6% $3d^{10}4s5p\ ^1P$
	410952.8[a]	410951.0	1.8	91% $3d^{10}4s5p\ ^1P$ + 6% $3d^{10}4s5p\ ^3P$
	438257.0[a]	438316.0	-59.0	67% $3d^{10}4p4d\ ^3D$ +31% $3d^{10}4p4d\ ^3P$
	442715.1[a]	442753.0	-37.9	68% $3d^{10}4p4d\ ^3P$ +32% $3d^{10}4p4d\ ^3D$
	467777.7[a]	467961.0	-183.3	96% $3d^{10}4p4d\ ^1P$
	491869.5[a]	491926.0	-56.5	86% $3d^{10}4p5s\ ^3P$ +12% $3d^{10}4p5s\ ^1P$
	503165.0[a,*]	500905.0	-	74% $3d^{10}4p5s\ ^1P$ +13% $3d^{10}4p5s\ ^3P$ +10% $3d^{10}4s6p\ ^1P$
	-	522187.0	-	99% $3d^{10}4s6p\ ^3P$
	526860.6	526856.0	-4.6	89% $3d^{10}4s6p\ ^1P$ +10% $3d^{10}4p5s\ ^1P$
	-	581604.0	-	97% $3d^{10}4s7p\ ^3P$
	583098.4	583098.0	0.4	96% $3d^{10}4s7p\ ^1P$
	617810.0	617700.0	110.0	91% $3d^{9}4s^{2}4p\ ^3P$ + 6% $3d^{9}4s^{2}4p\ ^3D$

	627399.0[b]	627509.0	-110.0	89% $3d^94s^24p$ ^1P +10%$3d^94s^24p$ ^3D
	630377.0[b]	632106.0	-	84% $3d^94s^24p$ ^3D + 8%$3d^94s^24p$ ^1P
2	110624.6[a]	110627.0	-2.4	100% $3d^{10}4s4p$ ^3P
	408852.8[a]	408852.0	0.8	99% $3d^{10}4s5p$ ^3P
	417154.5[a]	417108.0	48.5	83% $3d^{10}4p4d$ ^3F +12%$3d^{10}4s4f$ ^3F +4%$3d^{10}4p\,4d$ ^1D
	427734.7	427631.0	103.7	91% $3d^{10}4p4d$ ^1D + 4%$3d^{10}4p4d$ ^3P
	438162.9[a]	438276.0	-113.1	57% $3d^{10}4p4d$ ^3P + 37%$3d^{10}4p4d$ ^3D +5%$3d^{10}4p4d$ ^1D
	443103.0[a]	443018.0	85.0	61% $3d^{10}4p4d$ ^3D +38%$3d^{10}4p4d$ ^3P
	450689.4[a]	450593.0	96.4	86% $3d^{10}4s4f$ ^3F +13%$3d^{10}4p4d$ ^3F
	498121.3[a]	498118.0	3.3	99% $3d^{10}4p5s$ ^3P
	522912.6	522916.0	3.4	99% $3d^{10}4s6p$ ^3P
	540557.0	540552.0	5.0	100% $3d^{10}4s5f$ ^3F
	-	582032.0	-	100% $3d^{10}4s7p$ ^3P
	-	587681.0	-	100% $3d^{10}4s6f$ ^3F
	-	610198.0	-	91% $3d^94s^24p$ ^3P + 7%$3d^94s^24p$ ^3D
	-	620195.0	-	88% $3d^94s^24p$ ^3F + 9%$3d^94s^24p$ ^3D
	-	625145.0	-	66% $3d^94s^24p$ ^1D +24%$3d^94s^24p$ ^3D +6%$3d^94s^24p$ ^3F + 4%$3d^94s^24p$ ^3P
	-	633778.0	-	60% $3d^94s^24p$ ^3D +33%$3d^94s^24p$ ^1D +5%$3d^94s^24p$ ^3F
3	419546.9[a]	419514.0	32.9	83% $3d^{10}4p4d$ ^3F +14% $3d^{10}4s4f$ ^3F
	431566.3[a]	431602.0	-35.7	60% $3d^{10}4s4f$ ^1F +37% $3d^{10}4p4d$ ^1F
	442956.8[a]	442700.0	256.8	97% $3d^{10}4p4d$ ^3D
	450961.1[a]	450962.0	-0.9	84% $3d^{10}4s4f$ ^3F +15% $3d^{10}4p4d$ ^3F
	480471.6[a]	480423.0	48.6	58% $3d^{10}4p4d$ ^1F +38% $3d^{10}4s4f$ ^1F
	540550.5	540560.0	-9.5	100% $3d^{10}4s5f$ ^3F
	544637.0	544639.0	-2.0	96% $3d^{10}4s5f$ ^1F
	-	587682.0	-	100% $3d^{10}4s6f$ ^3F
	-	589364.0	-	99% $3d^{10}4s6f$ ^1F
	-	613927.0	-	59% $3d^94s^24p$ ^3F +33% $3d^94s^24p$ ^1F +7% $3d^94s^24p$ ^3D
	-	625417.0	-	63% $3d^94s^24p$ ^3D +35% $3d^94s^2\,4p$ ^1F
	-	629459.0	-	38% $3d^94s^24p$ ^3F +32% $3d^94s^2\,4p$ ^1F +30% $3d^94s^24p$ ^3D

4	422807.7	422781.0	33.7	82% $3d^{10}4p4d\,^3F$ +18% $3d^{10}4s4f\,^3F$
	451343.9[a]	451468.0	-126.1	82% $3d^{10}4s4f\,^3F$ +18% $3d^{10}4p4d\,^3F$
	540577.0	540572.0	5.0	100% $3d^{10}4s5f\,^3F$
	-	587686.0	-	100% $3d^{10}4s6f\,^3F$
	-	618754.0	-	100% $3d^9 4s^2 4p\,^3F$

[a]Levels established by Chirlov and Joshi Ref.[11].
*Levels not included to fitting (see text in Ref. [11]).
[b]Level reported in Ref.[18].

Table 6.3: LSF and HFR energy parameters of Br VI in cm^{-1}.

Configuration	Parameter	LSF	accuracy	HF	LSF/HF
Even configurations					
$3d^{10}4s^2$	$E_{AV}(3d^{10}4s^2)$	5429.0	76.0	5782.0	
$3d^{10}4p^2$	$E_{AV}(3d^{10}4p^2)$	255117.1	36.0	253097.0	1.010
	$F^2(4p,4p)$	50861.3	173.0	64976.1	0.783
	$\xi(4p)$	4608.0	40.0	4164.5	1.106
$3d^{10}4s4d$	$E_{AV}(3d^{10}\,4s\,4d)$	307774.6	40.0	304827.2	1.011
	$\xi(4d)$	328.0	36.0	279.3	1.174
	$G^2(4s,4d)$	33465.9	285.0	45737.9	0.732
$3d^{10}4s5d$	$E_{AV}(3d^{10}\,4s5d)$	479311.5	32.0	476840.4	1.006
	$\xi(5d)$	120.8	(fixed)	120.9	0.999
	$G^2(4s,5d)$	5707.1	187.0	10366.8	0.551
$3d^{10}4s6d$	$E_{AV}(3d^{10}\,4s6d)$	558108.4	37.0	555840.3	1.005
	$\xi(6d)$	63.0	(fixed)	63.0	1.000
	$G^2(4s,6d)$	2372.2	(fixed)	4313.1	0.550
$3d^{10}4s5s$	$E_{AV}(3d^{10}4s5s)$	362324.5	51.0	359597.1	1.009
	$G^0(4s,5s)$	4043.3	45.0	5772.2	0.700
$3d^{10}4s6s$	$E_{AV}(3d^{10}\,4s6s)$	501994.7	51.0	499182.9	1.006
	$G^0(4s,6s)$	1278.0	46.0	1926.4	0.663
$3d^{10}4s7s$	$E_{AV}(3d^{10}\,4s7s)$	570470.5	51.0	567296.9	1.006
	$G^0(4s,\,7s)$	549.1	46.0	911.4	0.602
$3d^{10}4s8s$	$E_{AV}(3d^{10}\,4s\,8s)$	609230.3	64.0	605869.6	1.006
	$G^0(4s,\,8s)$	383.4	(fixed)	511.2	0.750
$3d^{10}4s5g$	$E_{AV}(3d^{10}\,4s\,5g)$	544535.4	37.0	541508.6	1.006
	$\xi(5g)$	1.2	(fixed)	1.2	1.000
	$G^4(4s,\,5g)$	1103.5	(fixed)	1471.4	0.750
$3d^{10}4s6g$	$E_{AV}(3d^{10}\,4s\,6g)$	593501.0	37.0	590605.1	1.006
	$\xi(6g)$	0.6	(fixed)	0.6	1.000
	$G^4(4s,6g)$	889.6	(fixed)	1186.2	0.750
$3d^{10}4s^2$ -$3d^{10}4p^2$	$R^1(4s,\,4s;\,4p,\,4p)$	66935.7	240.0	86395.0	0.775
$3d^{10}4s^2$ -$3d^{10}4s6s$	$R^0(4s,\,4s;\,4s,\,6s)$	1726.8	6.0	2228.8	0.775
$3d^{10}4p^2$ -$3d^{10}4s4d$	$R^1(4p,\,4p;\,4s,\,4d)$	56790.0	204.0	73299.9	0.775
$3d^{10}4p^2$ -$3d^{10}4s5d$	$R^1(4p,\,4p;\,4s,\,5d)$	22348.8	80.0	28846.1	0.775
$3d^{10}4p^2$ -$3d^{10}4s6d$	$R^1(4p,\,4p;\,4s,\,6d)$	13047.4	47.0	16840.5	0.775
$3d^{10}4p^2$ -$3d^{10}4s6s$	$R^1(4p,\,4p;\,4s,\,6s)$	-134.8	0.0	-174.0	0.775
	$R^2(4s,\,4d;\,5d,\,4s)$	15554.5	56.0	20076.6	0.775
$3d^{10}4s4d$ -$3d^{10}4s6d$	$R^2(4s,\,4d;\,6d,\,4s)$	9335.4	34.0	12049.4	0.775
$3d^{10}4s5d$ -$3d^{10}4s6d$	$R^2(4s,\,5d;\,6d,\,4s)$	5121.5	18.0	6610.4	0.775
$3d^{10}4s5s$ -$3d^{10}4s6s$	$R^0(4s,\,5s;\,6s,\,4s)$	2538.3	9.0	3276.2	0.775
	σ	64.0			
Odd configuration					
$3d^{10}4s4p$	$E_{AV}(3d^{10}4s\,4p)$	121017.7	65.0	116989.8	1.039
	$\xi(4p)$	4698.2	107.0	4175.7	1.125
	$G^1(4s,4p)$	72085.3	224.0	86462.7	0.834
$3d^{10}4s5p$	$E_{AV}(3d^{10}4s5p)$	410023.7	66.0	406663.4	1.009
	$\xi(5p)$	1284.9	102.0	1437.6	0.894
	$G^1(4s,5p)$	7336.3	257.0	9163.5	0.805
$3d^{10}4s6p$	$E_{AV}(3d^{10}\,4s\,6p)$	522812.5	89.0	521251.1	1.004
	$\xi(6p)$	683.5	(fixed)	683.5	1.000
	$G^1(4s,6p)$	2468.0	(fixed)	3290.8	0.750
$3d^{10}4s7p$	$E_{AV}(3d^{10}\,4s7p)$	582026.1	118.0	579444.8	1.005
	$\xi(7p)$	380.4	(fixed)	380.5	1.000

	$G^1(4s,7p)$	1213.2	(fixed)	1617.7	0.750
$3d^{10}4p4d$	$E_{AV}(3d^{10}4p\ 4d)$	438306.3	39.0	432352.9	1.015
	$\xi(4p)$	4628.1	80.0	4281.6	1.081
	$\xi(4d)$	287.0	(fixed)	287.0	1.000
	$F^2(4p,4d)$	40546.0	(fixed)	54061.8	0.750
	$G^1(4p,4d)$	47592.6	241.0	65955.1	0.722
	$G^3(4p,4d)$	30773.8	279.0	41190.0	0.747
$3d^{10}4p5s$	$E_{AV}(3d^{10}\ 4p\ 5s)$	496540.9	86.0	491698.9	1.011
	$\xi(4p)$	4915.0	104.0	4448.6	1.105
	$G^1(4p,5s)$	7122.4	(fixed)	8379.3	0.850
$3d^{10}4s4f$	$E_{AV}(3d^{10}\ 4s\ 4f)$	447380.0	79.0	443293.7	1.010
	$\xi(4f)$	4.7	(fixed)	4.8	0.979
	$G^3(4s,4f)$	15516.6	958.0	19112.9	0.812
$3d^{10}4s5f$	$E_{AV}(3d^{10}4s5f)$	540788.7	60.0	537294.7	1.007
	$\xi(5f)$	2.7	(fixed)	2.7	1.000
	$G^3(4s,5f)$	5845.2	498.0	8676.5	0.674
$3d^{10}4s6f$	$E_{AV}(3d^{10}4s6f)$	587910.9	(fixed)	587916.5	1.001
$3d^94s^24p$	$E_{AV}(3d^94s^24p)$	622455.0	83.0	618357.7	1.007
	$\xi(3d)$	3333.6	(fixed)	3333.7	1.000
	$\xi(4p)$	4631.5	(fixed)	4631.6	1.000
	$F^2(3d,4p)$	31529.1	(fixed)	37093.2	0.850
	$G^1(3d,4p)$	9162.1	(fixed)	12216.2	0.750
	$G^3(3d,4p)$	8689.7	(fixed)	11586.4	0.750
$3d^{10}4s4p - 3d^{10}4s5p$	$R^0(4s,4p;4s,5p)$	3053.1	14.0	3574.7	0.854
	$R^1(4s,4p;5p,4s)$	17920.0	85.0	20982.1	0.854
$3d^{10}4s4p - 3d^{10}4s6p$	$R^0(4s,4p;4s,6p)$	1548.0	7.0	1812.5	0.854
	$R^1(4s,4p;6p,4s)$	9012.7	43.0	10552.8	0.854
$3d^{10}4s4p - 3d^{10}4s7p$	$R^0(4s,4p;4s,7p)$	987.9	5.0	1156.7	0.854
	$R^1(4s,4p;7p,4s)$	5729.2	27.0	6708.2	0.854
	$R^2(4s,4p;4d,4p)$	47043.6	222.0	55081.8	0.854
$3d^{10}4s4p - 3d^{10}4p5s$	$R^1(4s,4p;4p,5s)$	3212.6	15.0	3761.4	0.854
	$R^0(4s,4p;5s,4p)$	624.4	3.0	731.2	0.854
	$R^1(4s,5p;6p,4s)$	4592.2	22.0	5376.8	0.854
$3d^{10}4s5p - 3d^{10}4s7p$	$R^1(4s,5p;7p,4s)$	3142.3	15.0	3679.3	0.854
$3d^{10}4s5p - 3d^{10}4p4d$	$R^2(4s,5p;4d,4p)$	7241.2	34.0	8478.4	0.854
$3d^{10}4s5p - 3d^{10}4p5s$	$R^1(4s,5p;4p,5s)$	33430.7	158.0	39143.0	0.854
	$R^0(4s,5p;5s,4p)$	5163.2	24.0	6045.4	0.854
	$R^1(4s,6p;7p,4s)$	1961.5	9.0	2296.7	0.854
$3d^{10}4s6p - 3d^{10}4p4d$	$R^1(4s,6p;4p,4d)$	-1266.2	-6.0	-1482.5	0.854
	$R^2(4s,6p;4d,4p)$	2682.5	13.0	3140.9	0.854
$3d^{10}4s6p - 3d^{10}4p5s$	$R^1(4s,6p;4p,5s)$	14829.3	70.0	17363.1	0.854
	$R^0(4s,6p;5s,4p)$	3033.4	14.0	3551.7	0.854
$3d^{10}4s7p - 3d^{10}4p\ 4d$	$R^1(4s,7p;4p,4d)$	-1139.5	-5.0	-1334.3	0.854
	$R^2(4s,7p;4d,4p)$	1355.4	6.0	1587.0	0.854
$3d^{10}4s7p - 3d^{10}4p5s$	$R^1(4s,7p;4p,5s)$	9322.6	44.0	10915.5	0.854
	$R^0(4s,7p;5s,4p)$	2086.9	10.0	2443.5	0.854
$3d^{10}4p4d - 3d^{10}4p5s$	$R^2(4p,4d;4p,5s)$	-7469.9	-35.0	-8746.2	0.854
$3d^{10}4p4d - 3d^{10}4s4f$	$R^1(4p,4d;4s,4f)$	47202.8	223.0	55268.3	0.854
	$R^2(4p,4d;4f,4s)$	30008.1	142.0	35135.5	0.854
$3d^{10}4p4d - 3d^{10}4s5f$	$R^1(4p,4d;4s,5f)$	24493.0	116.0	28678.2	0.854
	$R^2(4p,4d;5f,4s)$	18904.8	89.0	22135.0	0.854
$3d^{10}4p4d - 3d^{10}4s6f$	$R^1(4p,4d;4s,6f)$	15568.0	73.0	18228.2	0.854
	$R^2(4p,4d;6f,4s)$	13057.4	62.0	15288.6	0.854
	$R^3(4s,4f;5f,4s)$	10764.0	51.0	12603.3	0.854
$3d^{10}4s4f - 3d^{10}4s6f$	$R^3(4s,4f;6f,4s)$	7598.6	36.0	8897.0	0.854
$3d^{10}4s5f - 3d^{10}4s6f$	$R^3(4s,5f;6f,4s)$	5343.8	25.0	6256.9	0.854
	σ	117.0			

The free configuration interaction integrals were linked to vary in the same ratio.
This table contains only the fitted interaction integrals whereas fixed ones at 80% of HFR are dropped from the table.

CONCLUSION

This thesis entitled "Atomic structure studies of Br in the vacuum ultraviolet region" comprises of four different atomic spectra of bromine viz; Br III, IV, V and VI. The analysis is based on the identification of 1480 transitions yielding a consolidated list of 446 energy levels of which 172 are new. 736 newly spectral lines have been classified.

The spectra for these analyses were photographed in the 300-2080 Å wavelength region on a 3-m normal incidence spectrograph at the Antogonish laboratory (Canada). The data below 300 Å was supplemented from the spectrograms recorded by Y.N. Joshi and van Kleef on 6.65-m grazing incidence spectrograph of Zeeman laboratory (Amsterdam). Spectrograms were measured with the help of Zeiss Abbe comparator at Aligarh. The impurity lines of C, O, N, Al and Si present on the spectrograms were used as internal standards for wavelength reduction. Using Mosfit, a polynomial fit program, the measured data was calibrated into the wavelength. For the optimization of energy levels we have used the computer program LOPT developed by A. Kramida of NIST (USA) and KLAS and....developed by G.J. Van Het Hof of Amsterdam. To transfer the final least-squares fitted output in the publication form a computer program TROUTK developed by A. Kramida is used.

The multi-configuration interaction calculations for the precise prediction of energy levels and transition arrays were done using the Cowan's computer programmes (RCN, RCN2, RCG and RCE). The scaling of energy parameters used for *ab-initio* calculations for each spectrum is derived from the corresponding isoelectronic sequence.

The thesis is divided into six chapters.

Chapter I deals with the basic theory of atomic spectra comprising of the Central-Field Theory, brief account of Hartree-Fock formalism, Slater Theory, Cowan's approach and ab initio calculation involved in our analyses. Moreover the Rydberg series, ionization potential and its spectroscopic determination, Isoelectronic sequences and their utility in the analysis of atomic spectra are also discussed in this chapter.

Chapter 2 is devoted to describe the experimental details of the work. We estimate the accuracy of our measured wavelengths for sharp and unblended lines to be ± 0.005 Å.

In Chapters 3-6, the analyses and discussions parts are described, dealing with third, fourth, fifth and sixth spectra of bromine i.e. Br III, Br IV, Br V and Br VI respectively.

In chapter 3, we have described revised and extended analysis of doubly ionized bromine (Br III). The ground configuration is $4s^24p^3$. The excited configurations $4s4p^4$ + $4s^24p^2$ (4d + 5d + 6d+5s + 6s+7s) in the even parity system and $4s^24p^2$ (5p + 4f) in the odd parity system have been studied. Our present investigation was based on experimental observations with full theoretical support for the confirmation and revision of the excited configuration $4p^25p$ and the work extended to study of a new $4p^24f$ configuration which was completely untouched. 159 levels have been established, 43 are new levels. Out of 504 spectral lines, 209 are newly classified. The spectrum is analyzed in the region 400–4600Å.

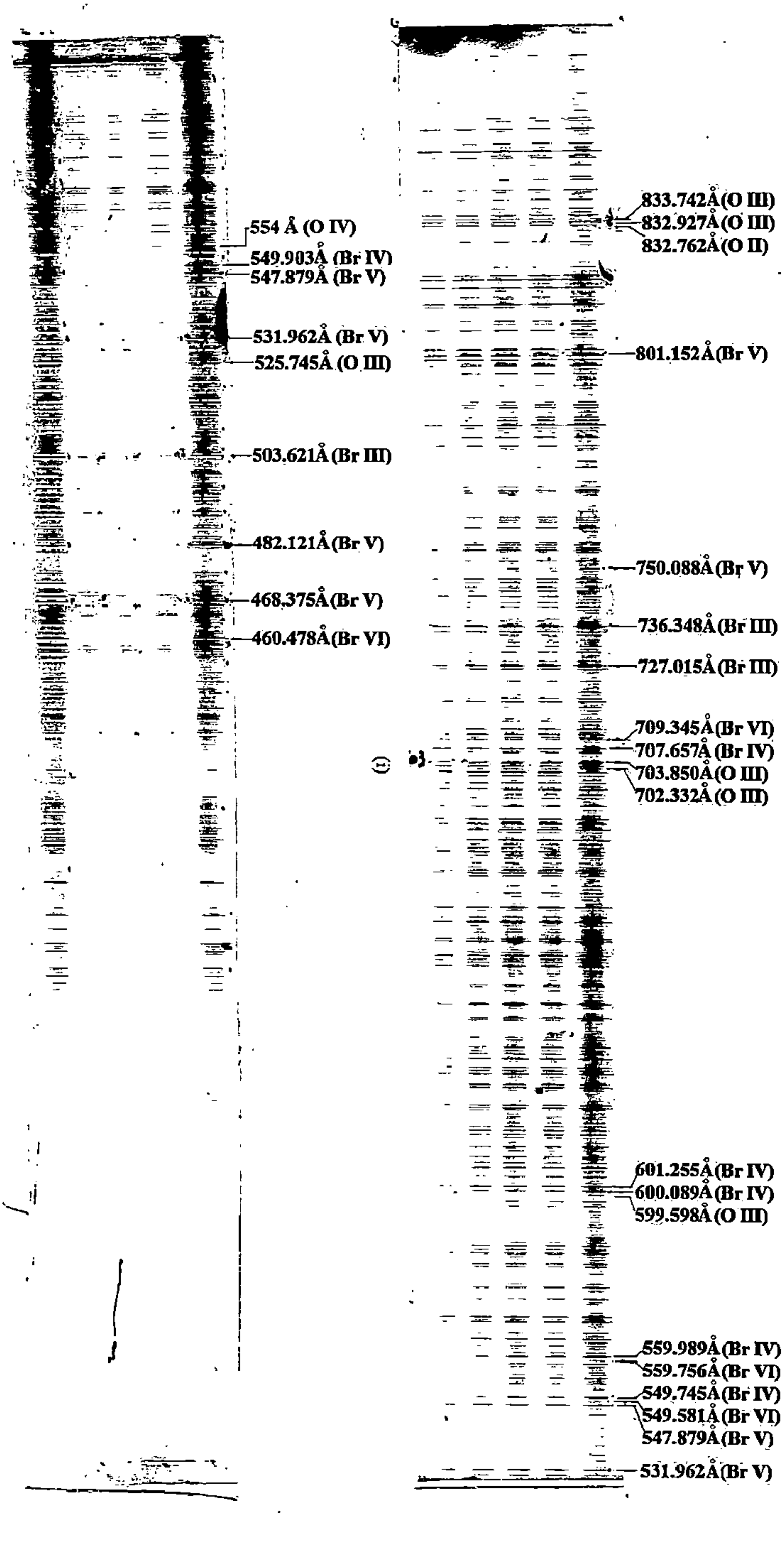
In Chapter 4, analysis of the Ge I-like spectrum of Br IV has been presented. The ground configuration $3d^{10}4s^24p^2$, the excited configurations $3d^{10}4s4p^3$ + $3d^{10}4s^24p$ (4d + 5d + 6d + 5s + 6s + 7s) in the odd parity system and $3d^{10}4s^24p$ (5p +4f + 5f) + $3d^{10}4s4p^2$ (4d+5s) + $3d^{10}$ $4p^4$ in the even parity system have been studied. 120 levels of Br IV have been established, 58 being new. Among 424 spectral lines, 277 are newly classified. The levels $4s4p^3$ $^5S_2$, $4s^24p4d$ $^3F_4$ and 4p5p ($^3P_{0,1}$, $^3D_{1,2}$, $^3S_1$) are revised. The ionization limit is determined as 385390±100 cm^{-1} (47.782± 0.012 eV). The spectrum has been studied in the 319–2350Å wavelength region.

An extended analysis of fifth spectrum of bromine Br V (Ga I-like) spectrum is described in the chapter 5. The spectrum is analyzed in the 200–2400Å wavelength region. The ground configuration of Br V $4s^24p$, the excited configurations $4s4p^2$+$4s^2$ (4d+5d+5s+6s+7s+5g+6g) + 4s4p (5p+4f) + $4p^24d$ in the even parity system and the $4p^3$ + $4s^2$ (5p+6p+7p+4f) +4s4p4d + 4s4p5s configurations in the odd parity system have been studied. Relativistic Hartree–Fock (HFR) and least squares fitted (LSF) parametric calculations were used to interpret the observed spectrum. 99 levels of Br V have now been established, 43 being new. Among 394 classified spectral lines, 181 are newly classified. The level $4s^27s$ $^2S_{1/2}$ is revised. The ionization limit is determined as 479657±200 cm^{-1} (59.470±0.025 eV).

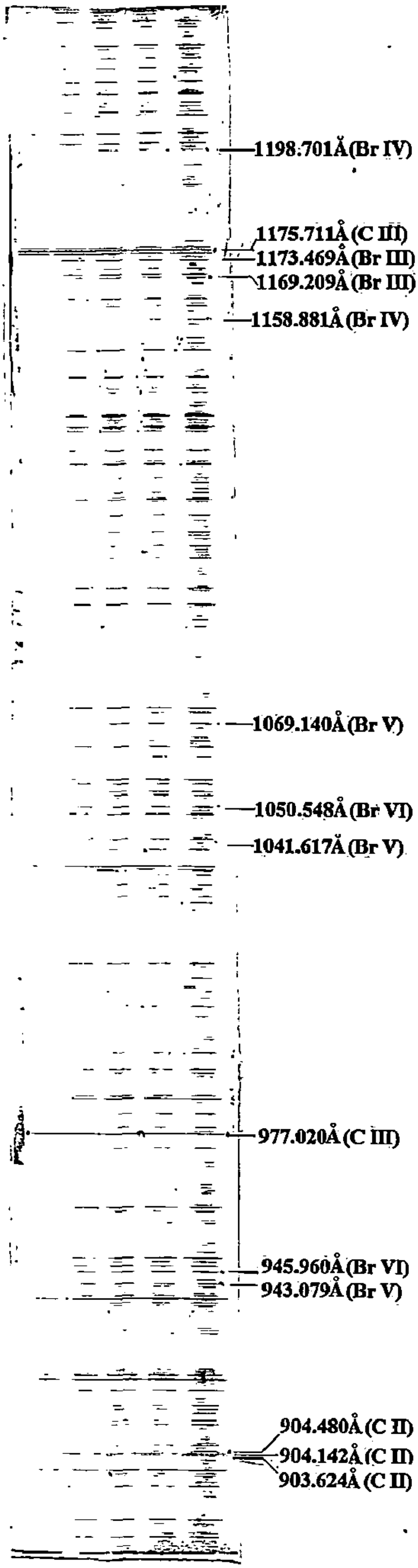
Chapter 6 described the revised and extended analysis of Br VI which is Zn I-like spectrum. The spectrum has been studied in the 150-2060Å wavelength region. The ground configuration of Br VI is $3d^{10}4s^2$ and the excited configurations $3d^{10}4s$ (4p+5p+6p+7p+4f+5f) + $3d^{10}4p4d$ + $3d^{10}4p5s$ in the odd parity system and $3d^{10}4s$ (4d+5d+6d+5s+6s+7s+8s+5g+6g) + $3d^{10}4p^2$ in the even parity system have been studied. The work extended to the study of new configurations $3d^{10}4s$(6s, 7s, 8s, 6p, 7p, 5d, 6d, 5f, 5g, 6g). Relativistic Hartree-Fock (HFR) and least squares fitted (LSF) parametric calculations were used to interpret the observed spectrum. 68 levels of Br VI have been established, out of which 28 are new. Two previously reported levels viz. 4p4d $^1D_2$ and $^3F_4$ were revised. Among 158 spectral lines, 69 are newly classified. The value of the ionization potential has been determined as 704850 ± 200 cm^{-1} (87.390 ± 0.025 eV).

In the last section conclusion of the work presented in this thesis and appendix are given. In Appendix spectrograms of bromine are reproduced covering the spectral region 300 - 2080Å. Prominent impurity lines of O, Al and C are marked together with strong Br III, IV, V and VI lines.

Our future plan is to continue the structure study of ionized atoms of different bromine spectra which could not be studied so far, for which we need extended spectra in the visible or ultraviolet region. That can be recorded freshly on 35 feet grating spectrograph as well as on 1.5m Wadsworth spectrographs of our laboratory. Particularly we are interested in Br II spectrum which lies in higher wavelength region. For Br VII and VIII spectra we would like to study the transitions between excited states.



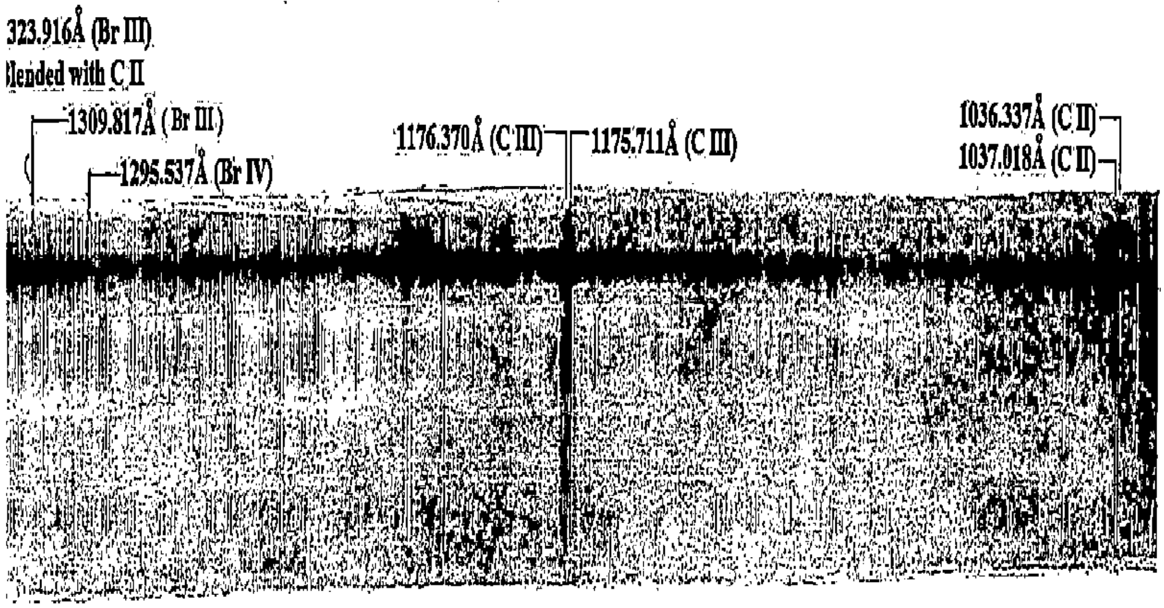
Appendix 1. Spectra of Br (i) 530-876 Å (ii) 300-606 Å.



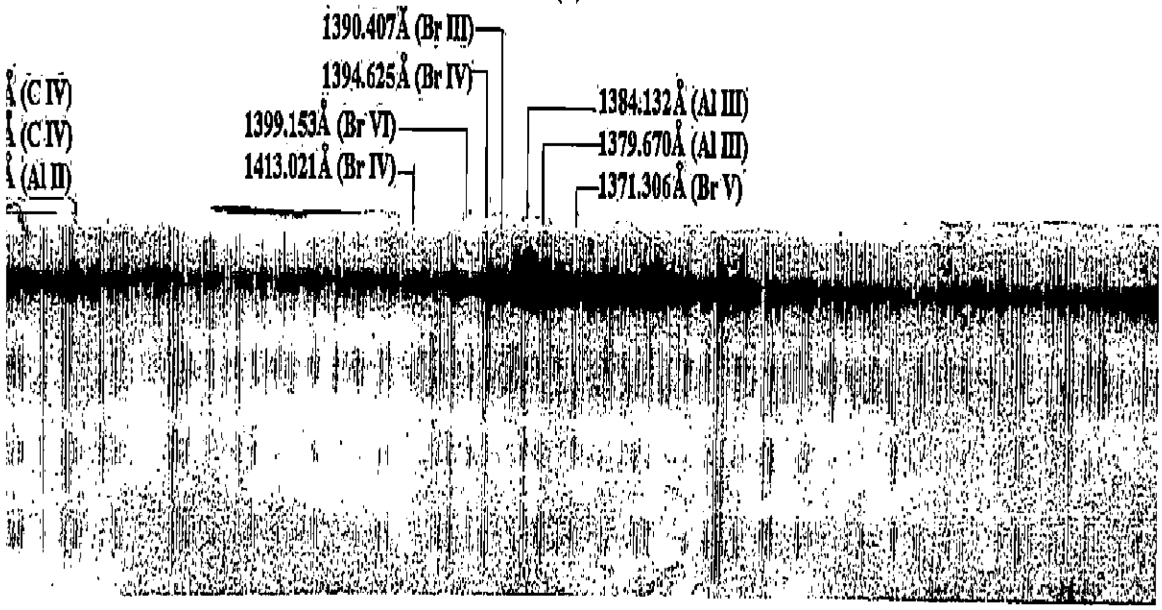
(iii)

Appendix 1. Spectra of Br: (iii) 883-1230 Å

Appendix 1. Spectra of Br: (iv) and (v) 1025-1551Å

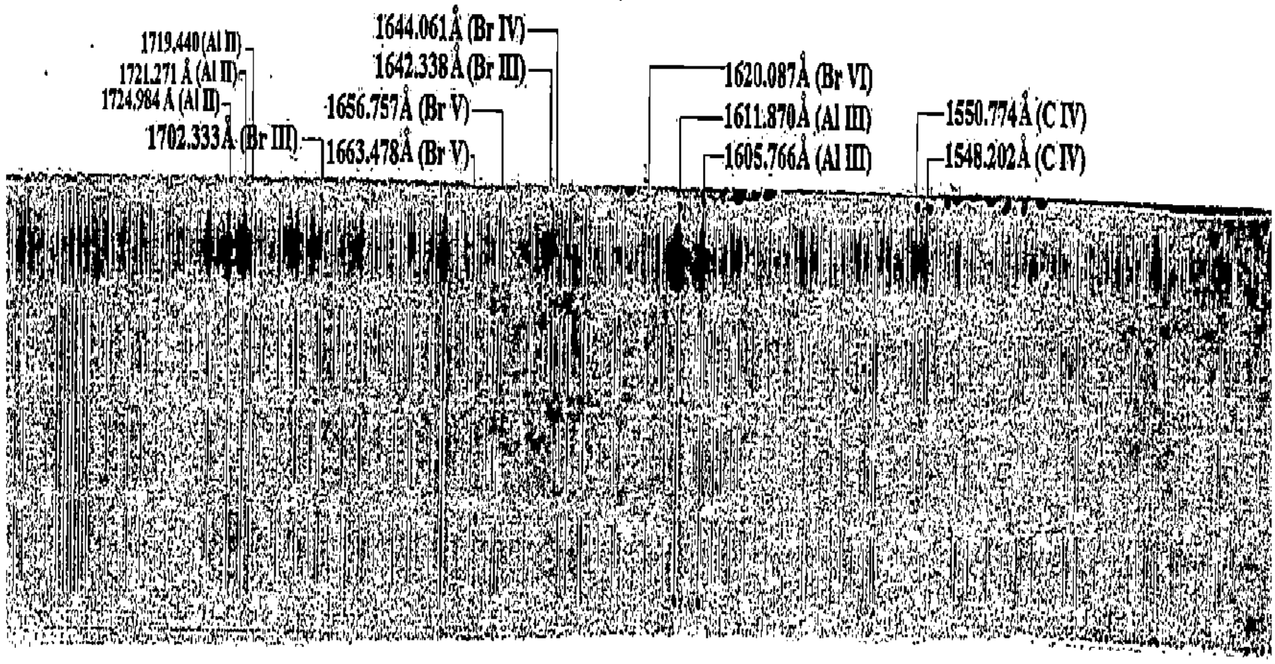


(iv)

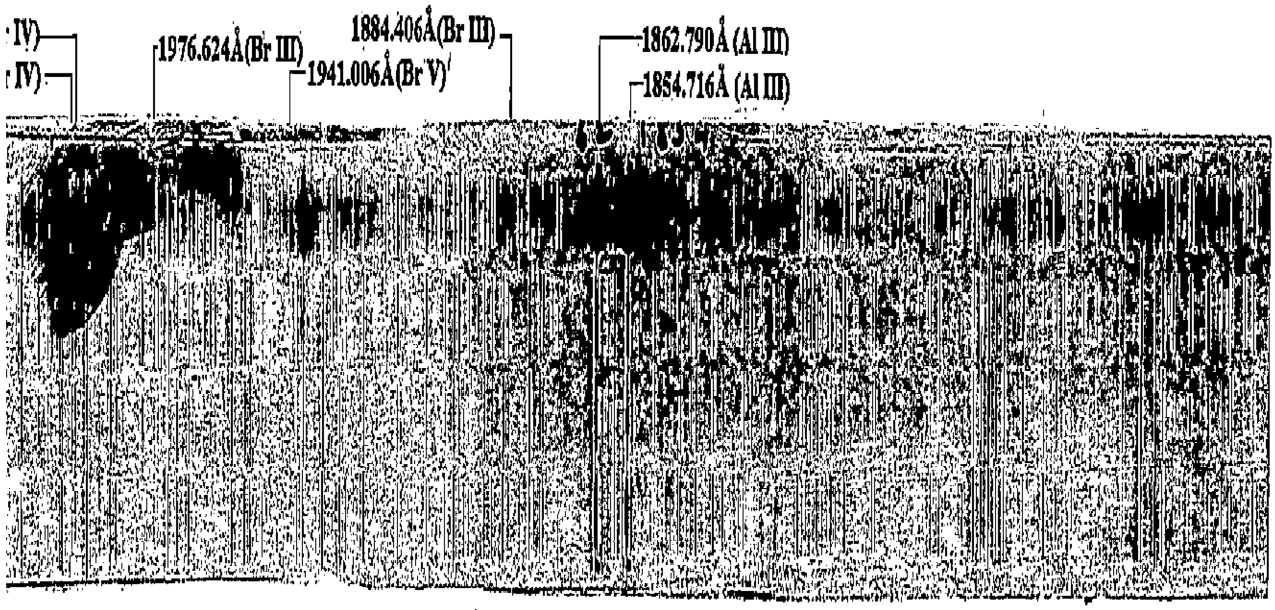


(v)

Appendix 1. Spectra of Br: (vi) 1465-1846 Å (vii) 1700-2080 Å



(vi)



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Revised and extended analysis of Br IV

A. Riyaz, K. Rahimullah, A. Tauheed *

Department of Physics, Aligarh Muslim University, Aligarh 202002, India

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ABSTRACT

The spectrum of three-times ionized bromine Br IV has been studied in the 319–2350 Å wavelength region. The spectrum was recorded on a 3-m normal incidence vacuum spectrograph at the St. Francis Xavier University, Antigonish (Canada) and 6.65-m grazing incidence spectrograph at the Zeeman laboratory (Amsterdam). The light sources used were a triggered spark and sliding spark, respectively. The ground configuration of Br IV $3d^{10}4s^24p^2$, the excited configurations $3d^{10}4s4p^3+3d^{10}4s^24p$ (4d+5d+6d+5s+6s+7s) in the odd parity system and $3d^{10}4s^24p$ (5p+4f+5f)+$3d^{10}4s4p^2$ (4d+5s)+$3d^{10}4p^4$ in the even parity system have been studied. Relativistic Hartree–Fock (HFR) and least squares fitted (LSF) parametric calculations were used to interpret the observed spectrum. 120 Levels of Br IV have now been established, 58 being new. Among 424 spectral lines, 277 are newly classified. The levels $4s4p^3$ $^5S_2$, $4s^24p4d$ $^3F_4$ and 4p5p ($^3P_{0,1}$, $^3D_{1,2}$, $^3S_1$) are revised. We estimate the accuracy of our measured wavelength for sharp and unblended lines to be ±0.005 Å. The ionization limit is determined as 385,390 ± 100 cm^{-1} (47.782 ± 0.012 eV).

1. Introduction

Three-times ionized bromine (Br IV) has neutral germanium-like (Ge I) spectrum with $3d^{10}4s^24p^2$ as the ground state configuration. The excited configurations are $4s4p^3$, $4s^24pnd$ ($n \geq 4$) and $4s^24pns$ ($n \geq 5$); and further excitations lead to $3d^{10}4s^24p$ (5p+6p+4f+5f)+$3d^{10}4s$ ($4p^24d+4p^25s$)+$3d^{10}4p^4$.

Tauheed et al. [1] revised the earlier work of Joshi and Budhiraja [2]. They studied the $4s^24p^2$–[$4s4p^3+4s^24p$ (4d+5d+6d+5s+6s+7s)] transition array in the wavelength region 320–1290 Å and reported 142 classified lines connecting 61 energy levels. They also reported the ionization limit at 385,400 ± 250 cm^{-1} (47.77 ± 0.03 eV). The present investigation was undertaken mainly due to the availability of extended data on bromine spectrum which lead us to extend the study of new excited configurations $3d^{10}4s^24p$ (5p+4f+5f)+$3d^{10}4s4p^2$(4d+5s)+ $3d^{10}4p^4$. The study of these new configurations is the only way one can establish the unknown levels ($^3F_4$) of the earlier reported configurations 4p4d, 4p5d and4p6d. The $^3F_4$ level cannot combine radiatively with the ground configuration as the highest *J* value of any ground level is only 2. This can be established through the observed transitions from 4p5p as well as from 4p4f levels. Further 4p5d and 4p6d level values were based on shorter wavelengths and hence can be improved through these transitions. This prompted us to undertake this investigation.

2. Experimental details

The spectrum of bromine was recorded in the 300–2080 Å wavelength region on a 3-m normal incidence vacuum spectrograph at the Antigonish laboratory in Canada. The spectrograph was equipped with 2400 lines/mm osmium coated concave grating having an inverse dispersion of 1.385 Å mm^{-1}. The triggered spark was used as excitation

* Corresponding author. Tel.: +91 983 740 4077; fax: +91 571 270 1001.
E-mail addresses: riyaz_ahemad25@yahoo.co.in (A. Riyaz), ahmadtauheed@rediffmail.com (A. Tauheed).

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Extended analysis of fifth spectrum of bromine: Br V

A. Riyaz*, A. Tauheed, K. Rahimullah

Department of Physics, Aligarh Muslim University, Aligarh 202002, India

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ABSTRACT

The fifth spectrum of bromine (Br V) has been studied in the 200–2400 Å wavelength region. The spectrum was photographed on a 3-m normal incidence vacuum spectrograph at the St. Francis Xavier University, Antigonish (Canada) and 6.65-m grazing incidence spectrograph at the Zeeman laboratory (Amsterdam). The light sources used were a triggered spark and sliding spark. The ground configuration of Br V is $4s^24p$. The excited configurations $4s4p^2+4s^2(4d+5d+5s+6s+7s+5g+6g)+4s4p(5p+4f)+4p^24d$ in the even parity system and the $4p^3+4s^2(5p+6p+7p+4f)+4s4p4d+4s4p5s$ configurations in the odd parity system have been studied. Relativistic Hartree–Fock (HFR) and least squares fitted (LSF) parametric calculations have been used to interpret the observed spectrum. 99 levels of Br V have now been established, 43 being new. Among 394 classified spectral lines, 181 are newly classified. The level $4s^27s$ $^2S_{1/2}$ is revised. We estimate the accuracy of our measured wavelengths for sharp and unblended lines to be ± 0.005 Å. The ionization limit is determined as $479{,}657 \pm 200$ cm^{-1} (59.470 ± 0.025 eV).

1. Introduction

Four-times ionized bromine (Br V) has neutral gallium-like (Ga I) spectrum with $4s^24p$ as the ground state configuration. The excited configurations are $4s4p^2$, $4s^2nd$ ($n \geq 4$) and $4s^2ns$ ($n \geq 5$). Further excitations lead to $4p^3+4s4p4d+4s4p5d+4s4p5s+4s4p6s+4s^2(5p+6p+7p+4f)+4s4p5p+4s4p4f+4s4p5f+4p^2(4d+5s)+4s^2(5g+6g+7g+\cdots)$ etc. configurations. The spectrum of Br V was first analyzed by Rao and Rao [1]. They studied $4s^24p$, $4s4p^2$, $4s^2(4d+5d)$ configurations and classified 12 spectral lines in the wavelength region 482–856 Å. Budhiraja and Joshi [2] revised the earlier analysis of Rao and Rao [1] and reported 15 levels based on lines in the 468–1471 Å region arising out of $4s^2(4p+5p)-(4s4p^2+4s^24d+4s^25s)$ transition array and estimated the ionization potential of Br V at 502,860 cm^{-1}.

Recently, Tauheed and Joshi [3] investigated Br V spectrum in more detail. They studied the configurations $4s^2(4p+5p+6p+4f)+4s4p(4d+5s)+4p^3$ in the odd parity system and $4s^2(4d+5d+5s+6s+7s)+4s4p^2$ in the even parity matrix with theoretical predictions by Cowan's code [4] in the wavelength region 316–1892 Å. They confirmed only 10 levels out of 15 reported by Budhiraja and Joshi [2], and revised 5 levels viz. $4s^25p$ $^2P_{1/2,\,3/2}$, $4s4p^2$ $^2S_{1/2}$, $^2D_{3/2}$ and $^2D_{5/2}$. Their analysis contains 216 classified lines connecting 57 energy levels and revised ionization limit at $480{,}670 \pm 200$ cm^{-1} (59.60 ± 0.02 eV).

The present investigation is undertaken mainly due to the availability of the data in the shorter wavelength region (below 316 Å) as well as in the higher wavelength region above 2000 Å which lead us to extend the study of new configurations like $4s^2(5g+6g+7p)$, $4s4p$ $(5p+4f)$ and $4p^24d$. Also, the availability of shorter wavelength data gave us a chance to verify the $4s^24p-4s^27s$ transitions which were missing in earlier work [3]. However, these transitions are not seen on the list and a revised level value

* Corresponding author.
E-mail address: riyaz_ahemad25@yahoo.co.in (A. Riyaz).

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Revised and extended analysis of Br VI

A. Riyaz, A. Tauheed *, K. Rahimullah

Department of Physics, Aligarh Muslim University, Aligarh 202002, India

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ABSTRACT

The spectrum of five times ionized bromine (Br VI) has been studied in the 150–2060 Å wavelength region. The spectrum was recorded on a 3-m normal incidence vacuum spectrograph at the Antigonish laboratory (Canada) and 6.65-m grazing incidence spectrograph at the Zeeman laboratory (Amsterdam) using a triggered spark light source. The ground configuration of Br VI is $3d^{10}4s^2$ and the excited configurations $3d^{10}4s$ (4p+5p+6p+7p+4f+5f)+$3d^{10}4p4d$+$3d^{10}4p5s$ in the odd parity system and $3d^{10}4s$ (4d+5d+6d+5s+6s+7s+8s+5g+6g)+$3d^{10}4p^2$ in the even parity system have been studied. Relativistic Hartree–Fock (*HFR*) and least squares fitted (*LSF*) parametric calculations were used to interpret the observed spectrum. Sixty-eight levels of Br VI have now been established, out of which 28 are new levels. Two previously reported levels viz. 4p4d $^1D_2$ and $^3F_4$ were revised. Among one hundred and fifty-eight spectral lines, 69 are newly classified. The accuracy of our wavelength measurements for sharp and unblended lines is ± 0.005 Å. The value of the ionization potential has been determined as 704850 ± 200 cm^{-1} (87.390 ± 0.025 eV).

1. Introduction

Five-times ionized bromine (Br VI) has neutral zinc-like (Zn I) spectrum with $3d^{10}4s^2$ as the ground state configuration. Most of the excited configurations are of the type $3d^{10}$ 4s $n\ell$ ($n \geq 4$) but the core excitation gives $3d^9 4s^2$ (4p+4f). The further excitations lead to $4p^2$, 4p4d, and 4p5s. The spectral data on ionized atoms is always important for plasma diagnostics as well as for spectroscopic databases. Consequently, this sequence has also been studied extensively [1–16]. Rao and Rao [8] reported 10 levels in Br VI from the low excited configurations 4s4p, 4s4d and $4p^2$ which was followed by Joshi and van Kleef [9], Churilov et al. [10] and finally by Churilov and Joshi [11] covering the configurations $3d^{10}4s^2$, $3d^{10}4s$(4p+5p+5s+4d+4f) and $4p^2$, 4p(4d+5s). In the present work, all the levels reported by Churilov et al. [10] were confirmed which shows that none of the Rao and Rao's level could be verified except 4s4p $^1P_1$. Also, 4s5p $^3P_0$ and $4p^2$ $^1S_0$ of Joshi and van Kleef [9] were revised. Churilov and Joshi [11] reported 17 new levels based on lines identification in the 400–1200 Å wavelength region arising out of transitions between $4s^2$–(4s4p+4s5p), $4p^2$–(4p4d+4p5s), 4s4d–(4s5p+4s4f) and 4s5s–(4s5p+4p5s).

The present investigation was undertaken mainly due to the availability of more precise and extended data on bromine spectrum which led us to extend the study of new configurations $3d^{10}4s$(6s, 7s, 8s, 6p, 7p, 5d, 6d, 5f, 5g, 6g).

2. Experimental details

The spectrum of bromine was recorded in the 300–2080 Å wavelength region on a 3-m normal incidence vacuum spectrograph at the Antigonish laboratory in Canada. The spectrograph was equipped with 2400 lines mm^{-1} osmium coated concave grating having an inverse dispersion of 1.385 Å mm^{-1}. The shorter wavelength 150–300 Å was recorded on a 6.65-m grazing

* Corresponding author. Tel.: +91 9837404077;
fax: +91 5712701001.
E-mail address: ahmadtauheed@rediffmail.com (A. Tauheed).

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